

STUDIES IN GEOGRAPHY 1

MÁRTON PÉCSI

TEN YEARS
OF
PHYSICO
GEOGRAPHIC
RESEARCH
IN HUNGARY



AKADÉMIAI KIADÓ, BUDAPEST

TEN YEARS OF
PHYSICOGEOGRAPHIC
RESEARCH IN HUNGARY

(STUDIES IN GEOGRAPHY NO. 1)

by
MÁRTON PÉCSI
D. Sc.

This book covers the research work carried out in physical geography by the team of the Geographical Research Institute of the Hungarian Academy of Sciences during the past ten years. The reader is acquainted with the detailed results of the Hungarian geographers' investigations into surface features resulting from fluvial erosion, deflation, slope movements, peneplanation, recent crust movements and periglacial processes. Information is given on research in loess morphology, terrace morphology, quaternary chronology. The trends and fundamental methods of applied geography and the conception of Hungarian morphological mapping are also dealt with. A detailed bibliography of the science of physical geography in Hungary is appended.



AKADÉMAI KIADÓ
BUDAPEST

STUDIES IN GEOGRAPHY

No. 1 .

STUDIES IN GEOGRAPHY
published by the
GEOGRAPHICAL RESEARCH INSTITUTE
of the
HUNGARIAN ACADEMY OF SCIENCES
No. 1

Editor
BÉLA SÁRFALVI

Chief editor
MÁRTON PÉCSI

Editorial board
GYÖRGY ENYEDI
SÁNDOR MAROSI
LÁSZLÓ SIMON
JENŐ SZILÁRD



AKADÉMIAI KIADÓ, BUDAPEST 1964

TEN YEARS OF PHYSICOGEOGRAPHIC RESEARCH IN HUNGARY

by

MÁRTON PÉCSI

D. Sc.



AKADÉMIAI KIADÓ

PUBLISHING HOUSE OF THE HUNGARIAN ACADEMY OF SCIENCES
BUDAPEST 1964

Supervised by
SÁNDOR MAROSI
and
JENŐ SZILÁRD

Translated
by
BÉLA KECSKÉS

© Akadémiai Kiadó, Budapest 1964

AK 440 g 6467

Printed in Hungary at the Academy Press, Budapest
Responsible for publication: Gy. BERNÁT Director of the Publishing House
of the Hungarian Academy of Sciences and of the Academy Press
Responsible editor: G. P. DIENES
Technical editor: A. FÜLÖP

CONTENTS

Introduction	7
Chapter 1. Observations made in studying the role of fluvial erosion and accumulation	11
<i>a)</i> Investigation of terraces	11
<i>b)</i> Study of the alluvial fans	12
<i>c)</i> Flood plains of rivers	15
<i>d)</i> Erosional ravines and gullies	18
<i>e)</i> Mechanism of fluvial erosion	18
Chapter 2. Investigation of the process and forms of deflation	20
<i>a)</i> Formation and morphology of blown-sand areas	20
<i>b)</i> Investigation of loesses and loess morphology in Hungary	23
Chapter 3. Chronological problems of the Quaternary	26
Chapter 4. The role of derasion in the modelling of the Earth's surface	30
<i>a)</i> Slope deposits affected by gelisolifluction and pluvionivation	30
<i>b)</i> Dells	40
<i>c)</i> Principal types of cryoturbation	47
Chapter 5. Denudation in general	57
<i>a)</i> Climatic geomorphology	57
<i>b)</i> Tropical peneplanation and formation of piedmont surfaces	57
<i>c)</i> Terraces and surfaces affected by cryoplenation	61
Chapter 6. Structural forms and recent crustal movements	64
Chapter 7. Hydrographic investigations	68
Chapter 8. Phytogeographical investigations	69
Chapter 9. Research methods	70
Chapter 10. Geomorphological mapping (synoptic geomorphological map of Hungary)	78
<i>a)</i> Development and objectives of geomorphological mapping in Hungary	78
<i>b)</i> Conception and legend of the synoptic geomorphological maps of Hungary	79
(i) Representation of complex form families	80
Types of plains	80
Types of mountains	80
(ii) Representation of genetic feature elements	81
(iii) Representation of slope morphology	81
(iv) Denotation of the age of surface features	82
(v) Orographic and hydrographic elements	82
Chapter 11. Investigations into the morphogenetical evolution	84
<i>a)</i> General examination of morphogenesis	84
<i>b)</i> Stages of morphogenetical evolution in Hungary since the Late Tertiary	85

Chapter 12. Geomorphological evolution of the individual regions of Hungary	88
<i>a)</i> Development of the Buda Mountains and of the Pest Plain	88
<i>b)</i> Development of the Hungarian section of the Danube Valley	91
(i) Flood plain horizons	91
(ii) Terraces	91
(iii) Intensity of the Pleistocene crustal movements as suggested by the dislocation of the Danube terraces	93
(iv) Possibility of the synchronous formation of Danube terrace systems	93
(v) Mechanism of the formation of the Danube terraces	94
(vi) Changes in the direction of flow of the Danube in Hungary since the appearance of the river	95
<i>c)</i> Morphogenetic problems of the Danube—Tisza Mid-Region	96
<i>d)</i> The geomorphological evolution of the Mezőföld	100
<i>e)</i> The formation of Lake Balaton and of the Transdanubian Hill Region	104
(i) Somogy Hill Region	104
(ii) Lake Balaton	109
(iii) Tolna Hill Region	111
<i>f)</i> The evolution of the Little Plain	112
(i) Morphogenesis of the basalt volcano ruins in the Little Plain	114
(ii) Morphogenesis of the Trans-Rába gravel sheet	116
(iii) Vas Ridge and Kemeneshát	118
Chapter 13. Future plans	122
Bibliography	123

INTRODUCTION

In 1952 the Hungarian Academy of Sciences founded a Geographical Research Institute for more effective and comprehensive geographical investigations in Hungary as well as for the co-ordination of work scheduled by the Academy on the different geographical institutions. At the time of its foundation the Geographical Research Institute was divided into three sections: one for physiographical, one for economico-geographical investigations and one for bibliography and documentation.

In the first year following the foundation of the Geographical Research Institute (GRI) the Physiographical Section had a staff of four to six research workers who started to investigate various subjects according to their individual interests mainly in the sphere of geomorphology, but in close relationship with palaeogeography and hydrogeology. As for the territories investigated, the first research themes embraced the Hungarian section of the Danube Valley, the region of the Mezőföld and the surroundings of Budapest. The subjects and their treatment were determined by the stage of development of physiography ten years ago, by the approach to the problems and by the methods applied at that time. Appropriate methods of investigation were available mainly for studying the morphology of terraces, loesses, running sands and karsts and, in general, the history of development of drainage (B. Bulla, J. Cholnoky, L. Kádár, A. Kéz, S. Láng, L. Lóczy, F. Schafarzik, E. Scherf, J. Sümeghy). These methods permitted us to start field observations as early as the summer of 1952.

No sampling methods were used in geomorphological investigations ten years ago. We relied mostly on field surveys, on the examination of exposures, on the measurement of morphological levels and on comparative studies. Papers on research methodology were scarce (Kéz 1935, 1942), yet the dialectico-materialistic approach to geomorphology in Hungary was of great assistance to us when starting our work.

Some of us were helped through the initial difficulties by the experience gained in the course of the geological mapping of the plains of Hungary during the previous years. We began our investigations in the field with primitive instruments, without any organized professional guidance. During the first one year and a half we simply acquainted ourselves with the territory to be studied and with the respective literature (1952—1953).

During the first five years (1952—1956), even though using traditional methods, we obtained considerable practical experience in the course of our geomorphological field research by carrying out surveys and observations in much greater detail. The results thus obtained confirmed and completed our earlier observations. In addition, some new statements were formulated. The opportunity of frequent consultations with the leading representatives

of the collaborating institutes and the cognate sciences promoted our job. Therefore we are particularly indebted to professors and scientific research workers B. Bulla, F. Hajósy, L. Kádár, B. J. Kakas, A. Kéz, M. Kretzoi, S. Láng, I. Miháلتz, P. Stefanovits, J. Sümeghy, F. Szentes for their valuable help.

Experience gained by our field work was analysed and developed in the course of frequent internal discussions. During these years it became clear that the former research methods were no longer adequate for detailed geomorphological investigations. To achieve new and well-established results, we had to rely on the analysis of the sampled material, to carry out borings and to gather and analyse data from bore-holes made for other purposes. The workers of the GRI were the first to use new methods in geomorphological investigation in Hungary: furthermore, having recognized the great possibilities of collective work, the GRI was the first to organize a team of research workers (geographers, geologists, hydrogeologists, botanists, climatologists, soil scientists) whose collaboration resulted in compiling, in a relatively short time, the big monograph *The Physical Aspect of Budapest* (Pécsi, Marosi, Szilárd 1958). This filled a large gap in our geographic literature. It was thus proved that all obstacles can be removed through collective and well organized work.

When characterizing the first five years of work in general, we have to mention that, in addition to field work, we regularly studied the foreign, chiefly Soviet, geographical literature. Although in most cases we could consult only selections from the Soviet literature, these still gave us useful guidance in matters of principle and methodology and in the application of scientific methods of dialectical materialism in our science.

The counterrevolution of 1956 and the confusion of ideas provoked by it hindered, for a few months, the growing activity of the Physiographical Section. However, life and work were normalized within a relatively short time.

In 1957 the monographic treatment of the material collected during earlier field investigations made considerable progress and this marked the beginning of the second phase (1957—1961) of the ten years' activity of the section. This period was characterized by the summing up of results of investigations and by the compilation of synthesizing monographs such as Pécsi (1958a) *Physical Aspect of Budapest*; Ádám, Marosi and Szilárd (1959) *Physical Geography of the Mezőföld*; Pécsi (1959a) *Formation and Morphology of the Danube Valley in Hungary*; Pécsi and Sárfalvi (1960) *Geography of Hungary*; Somogyi (1960) *Evolution of the Drainage System of Hungary*; Pécsi (1961e) *Influence of the Quaternary Corrosive Processes on Morphological Evolution and on Sedimentation in Hungary* (all in Hungarian).

1. Members of the Physiographical Section generally investigated geomorphological subjects, and for other branches of physiography collaboration with specialists of other institutions was necessary at the beginning. Later it became evident that, in order to carry on, complex physiographical studies in perfect agreement with the various branches had to be completed by specialists skilled in the geography of soils, phytogeography and hydrogeography. In addition, we started a postgraduate training of the

research workers mainly in geomorphology to enable them to investigate the geography of soils, the climate and hydrography. We hope, therefore, that in the future all chapters of the monographs may be written by the members of the Institute, themselves, in close collaboration with all branches of geography.

2. In the course of field investigations and particularly when compiling the monographs it was found impossible to confirm or complete the results of the earlier investigations and to obtain new reliable ones without extending the scope of the geomorphological research methods. In Hungary the research workers of the Physiographical Section took important steps in developing the methods of geomorphological research (Pécsi and Pécsi-Donáth 1959, 1960; Pécsi 1959a).

3. In the course of research and compilation work important changes took place in our approach to the analysis of the surface relief, too. Heated debates within the Section on questions of attitude considerably pushed schematical formalism in geomorphology into the background. This will have an effect particularly on subsequent studies. Schematism was gradually overcome not only in the classification of forms and their historical subdivision by ages, but also in the interpretation of the processes modelling the surface of the earth. This is chiefly the result of the application of new analytic methods and of the new outlook based upon climatical morphology which, besides fluvial erosion and deflation, takes more and more widely into account the processes of solifluction, the redeposition of the material on slopes by gravitation in general, and the role of soil formation.

4. Our opinion concerning the objective of geomorphological investigations has also undergone important changes. The relief as a whole, the history of its development, individual features and formations yielded by physical processes are no longer evaluated for their own sake, but rather on account of practical considerations. These changes were promoted by the recurring practical demands and by the criticism, to which the schematic geomorphological views were repeatedly subjected.

Nevertheless, little has been done so far in geomorphological investigations towards satisfying practical demands and even less in establishing basic principles and methods. Requirements have gradually become more complex, but no appropriate examples of satisfying them are available either in Hungary or abroad. However, we have started to make efforts to solve this problem. Our first step was an attempt to undertake geomorphological mapping on the basis of the similarly practical endeavours of Soviet, Polish and French geographers. However this necessitates that Hungarian economic geographers and planning organs should raise concrete problems as we cannot content ourselves with mere generalities.

5. Collective work was proved to be necessary also in physiographical research and helped the publication of several synthesizing monographs of great importance within a relatively short time.

The activity of the Physiographical Section of the Geographical Research Institute during the past ten years will now be briefly described.

OBSERVATIONS MADE IN STUDYING THE ROLE
OF FLUVIAL EROSION AND ACCUMULATION

The process of erosion has been most often and most thoroughly studied by our team. When our field work was started, investigations in Hungary were influenced by the recently developed theory and method of climatic geomorphology (Bulla 1954a, 1954b, 1954c). Among the external forces shaping the surface of the earth, stress was laid on the role of fluvial erosion and of accumulation, these being the most thoroughly investigated processes. In this respect, we could largely rely upon the fruitful activity of our predecessors.

a) *Investigations of Terraces*

In this field we could rely on several decades of scientific research. We first studied terrace-morphological questions of the Danube Valley. After confirming and completing earlier observations we could derive new information which helped to amplify the achievements of earlier terrace-morphological investigations (Pécsi 1953, 1954, 1956c).

It has been found that in the Danube Valley synchronous terraces belonging to the same phase lie at different levels, and that terrace portions of the same height do not belong to the same terrace horizon along the whole length of the river. The number of terraces and their relative height can show remarkable differences in the tectonically different sections of the Danube Valley (Pécsi 1956c, 1957b, 1959a). We have: 1. flood plain valley sections without terraces, 2. alluvial fan sections with four or five terraces on the edge of plains, 3. valley sections with six or seven terraces in the highlands (Figs 1, 2, 3). In the course of our geomorphological research work in the Danube Valley we have drawn its detailed terrace-morphological map (Pécsi 1956c, 1959a). Contrary to the climatic factor previously stressed in our geomorphological literature, we emphasized and proved the important role of the tectonic factor (Pécsi 1956a—c). Bulla (1956b) relying partly on these data called attention to the fact that the promoting effect of climatic changes on the formation of terraced valleys is manifest only in the relatively rising portions of the earth crust thus adding new aspects to the study of the latter. With permanently sinking lowlands, irrespective of the climatic effect, accretion is characteristic during the period of sinking. The formation of the terraces of the Danube proved to belong to an earlier period than was previously believed. According to Pécsi (1956b, c, 1959a), the oldest terrace of the Danube might have been formed at the end of the upper Pliocene (Table I). According to Ádám (1959b) and Góczán (1960a), the oldest drift of the Danube in Hungary dates from the beginning of the Pleistocene.

In the Budapest reach of the Danube, the terrace horizon no. II, i.e. the urban horizon previously believed to date from the Last Glaciation, was

TABLE I
Terraces of the Hungarian section of the Danube
(according to M. Pécsi)

13

Designation	Time of formation of the terraces	Height in m above Danube level			
		Győr	Duna. almás	Visegrád	Budapest
Flood plain	late Holocene	3	3	—	3
Terrace No I	early Holocene and late Holocene	5	5	6	6
Terrace No IIa	Würm end	10	10	14	10
Terrace No IIb	beginning of Würm*	20	27	26	20
Terrace No III	middle Pleistocene (Riss)	30	47	80	30
Terrace No IV	early Pleistocene (Mindel)	45	78	140	53
Terrace No V	lower Pleistocene (Günz)	—	120	200	
Terrace No VI	end of Pliocene, beginning of Pleistocene (Danube phase)	—	170	230	
Terrace No VII	upper Pliocene	—	120	275	

* young Riss in terms of Büdel's division of Pleistocene

divided by Góczán (1955) and Marosi (1955) into two horizons (terraces II/a and II/b). These two horizons were also recognized in the highland and the Kisalföld (Little Plain) reaches of the Danube (Pécsi 1956c). The older Danube terraces near Budapest and on the border of the Little Plain, were proved not to be transient ones, but terraces of alluvial fans (Pécsi 1956c, Pécsi, Pécsi-Donáth 1960) (Figs 4, 5).

Summing up our experiences gained during the detailed examination of terraces, we have developed new gap-filling methods of investigation based upon the combined analysis of the material collected and on broad comparisons (Pécsi 1959a, Pécsi, Pécsi—Donáth 1960).

b) *Study of the Alluvial Fans*

Beside studying the history of the development of the talus fans of several small rivers, we have characterized in detail the alluvial fans of the Danube in the Little Plain (Pécsi 1959a) and in the Danube—Tisza Mid-Region (Bulla 1951, 1953, Pécsi 1960b, 1960c, 1962b), the alluvial fan of the Rába (Somogyi 1961), several larger ones of the Mezőföld (Ádám, Marosi and Szilárd

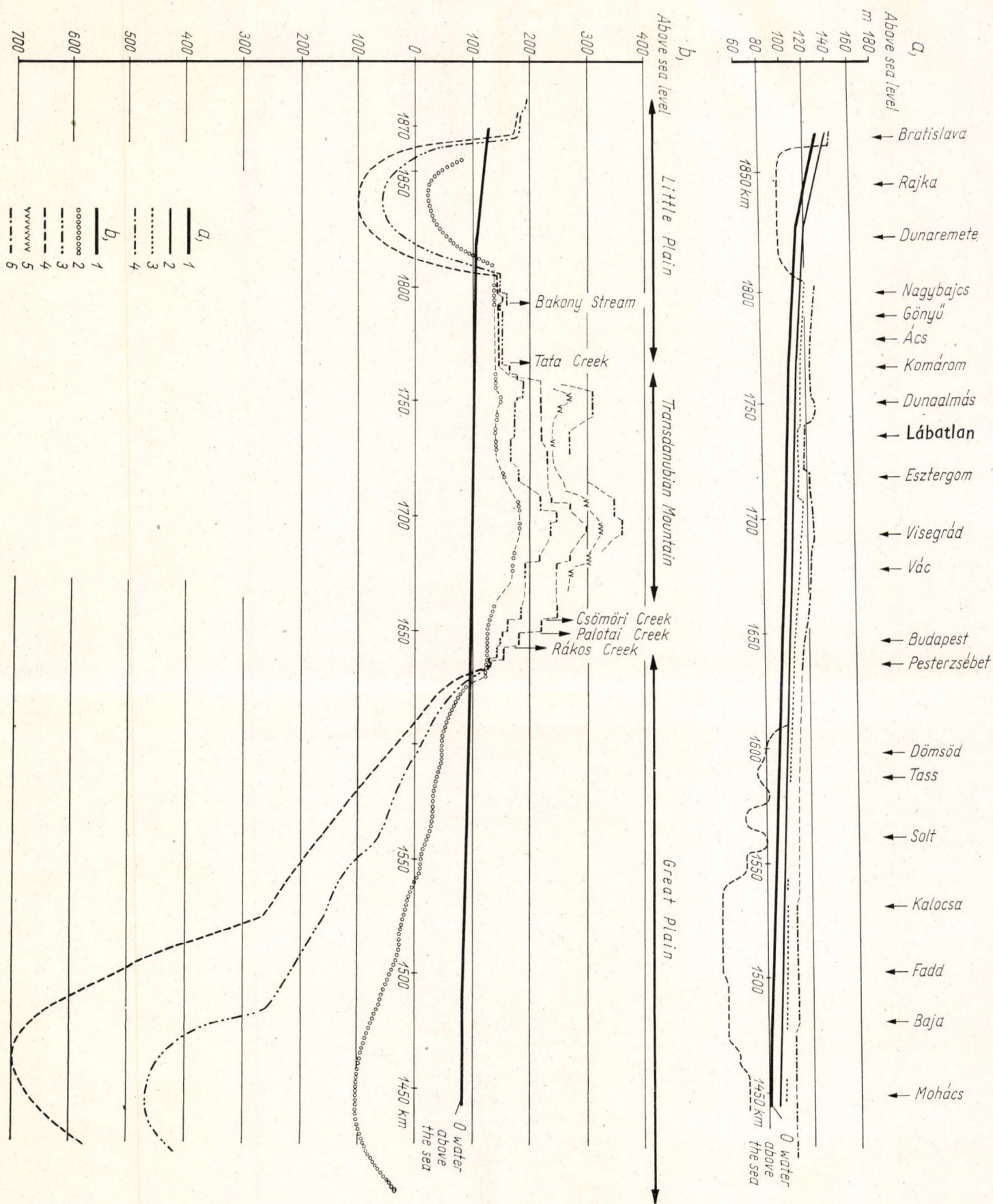


Fig. 1. Position of Danube terraces in the Hungarian section according to Pécsi (1958): a — lower-terrace (1-6) and higher-terrace (1-6) curves; b — curve of the 0 point of the Danube, 2 — level of terrace I, i.e. of the high flood plain, 3 — terrace II/a, end of late Pleistocene (Würm), 4 — terrace II/b, beginning of late Pleistocene (Würm); 1 — curve of the 0 point of the Danube, 2 — terrace III, middle Pleistocene (Riss), 3 — terrace IV, earlier Pleistocene (Mindel), 4 — terrace V, lower Pleistocene (Günz), 5 — terrace VI, end of Pliocene — beginning of Pleistocene (Dunabeg phase), 6 — terrace VII, end of Pliocene. The position of the alluviums deposited synchronously with the formation of the terraces below the 0 point of the Danube in the Little and Great Plains is schematically represented.

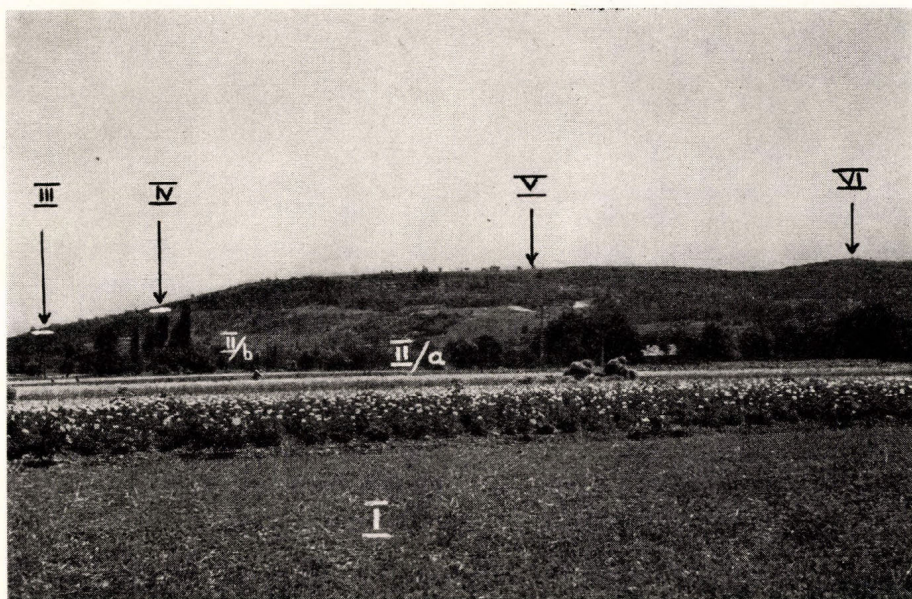


FIG. 2. Danube terraces south of Dunaalmás (Photo E. Vajda)

The flood plain in the foreground is followed by terraces (nos I, II/a, II/b, III, IV, V and VI) having heights of 12, 20, 40, 70, 110 and 160 m. The wide terrace V and the terrace VI are covered with thick travertine

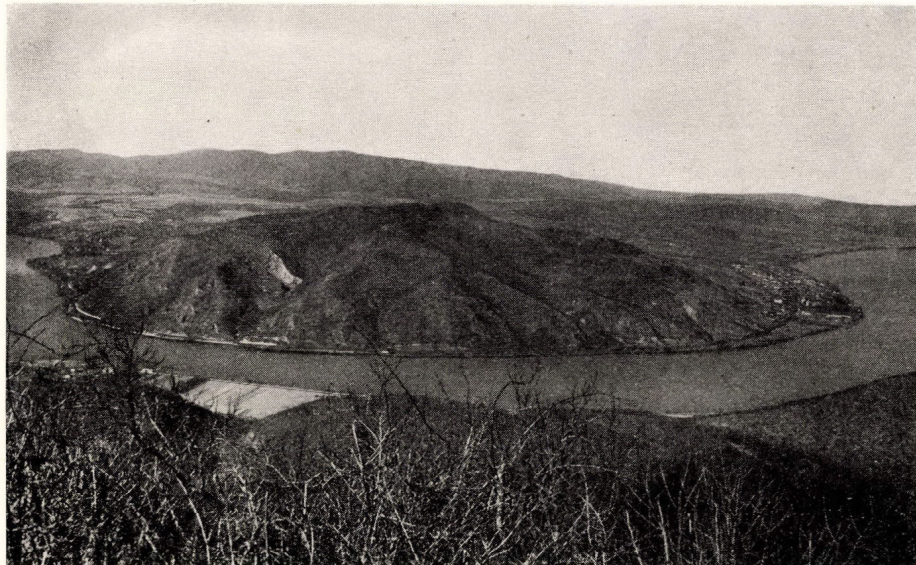


FIG. 3. The Danube Bend at Visegrád, seen from Prédikálószték. The Börzsöny Mountains in the background (Photo E. Vajda)

1959) and of the Transdanubian Hill Region (Ádám, Góczán, Marosi, Somogyi and Szilárd 1962). Beside explaining their development, we have also defined the geographical position of the aquifers included in the alluvial fans and

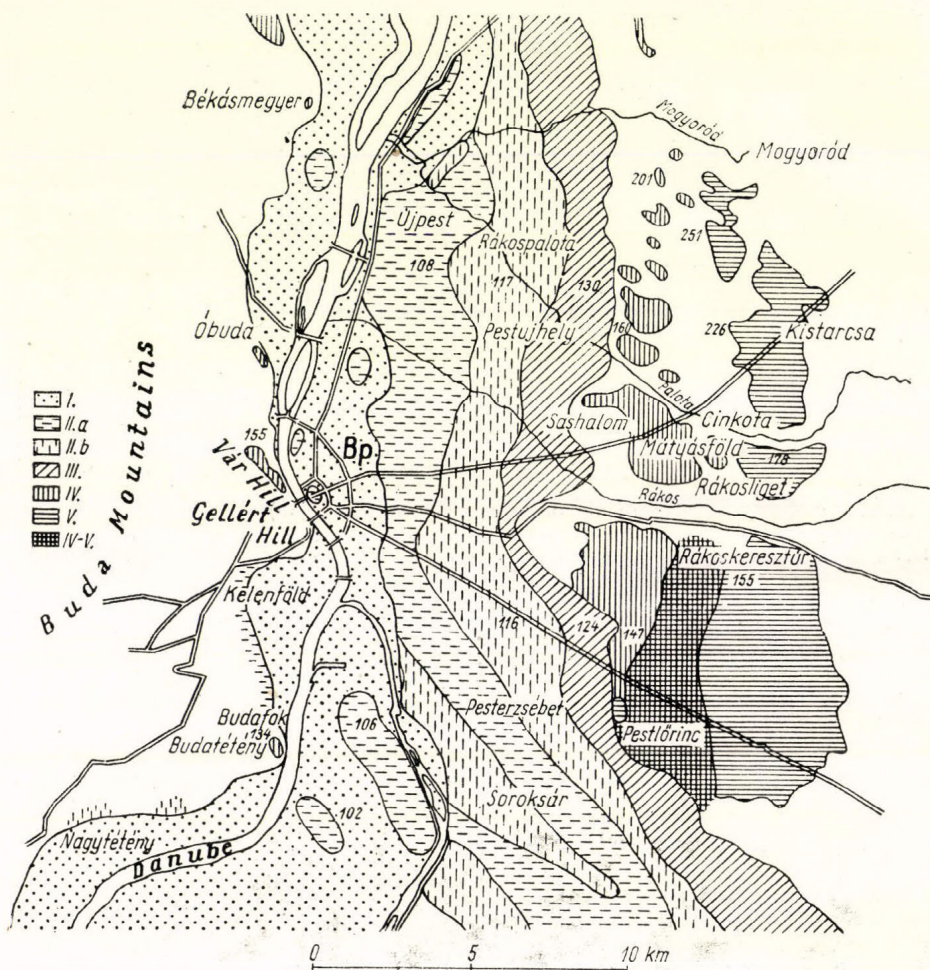


FIG. 4. Alluvial fan terraces of the Danube at the border of the Great Plain, according to Pécsi (1958).

I — Holocene flood plain horizons, II/a — terrace from the end of late Pleistocene (W), II/b — terrace from the beginning of late Pleistocene (W), III — middle Pleistocene terrace (R), IV — earlier Pleistocene terrace (M), V — lower Pleistocene alluvial terrace (G — pre-G), IV-V — the material of terrace IV laid on terrace V, Bp — the inner districts of Budapest

analysed the material of the sediments forming them. The results of these investigations have some practical value, too. We have estimated the quantities of building materials available and published the profiles which can be utilized in planning work.

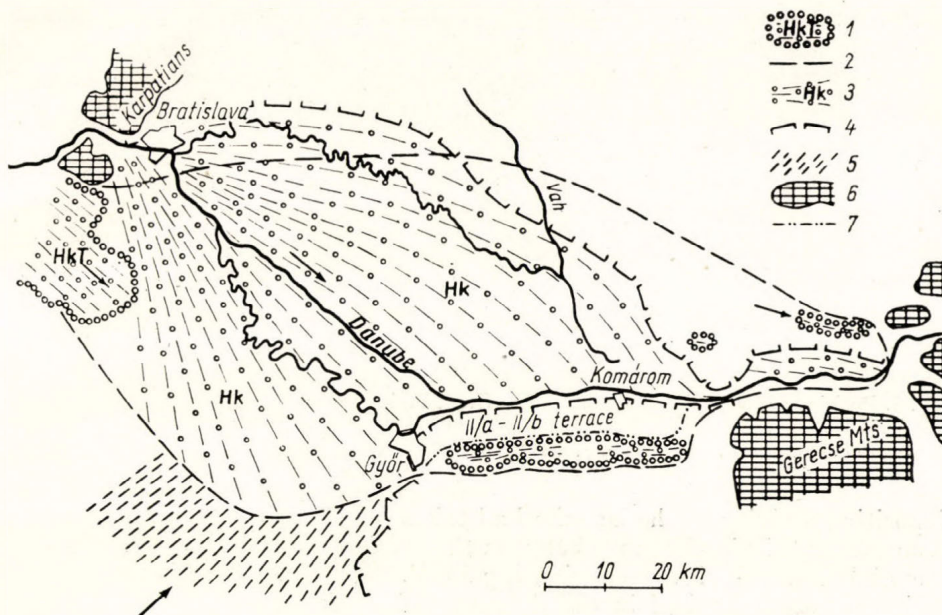


Fig. 5. Position of the alluvial fans of the Danube in the Little Plain, according to Pécs
 1 — Outliers of an older alluvial fan terrace, 2 — reconstructed boundary lines of an older alluvial fan, 3 — more recent alluvial fan, 4 — boundary lines of the more recent alluvial fan, 5 — Holocene alluvial fan of Rába-Répece, 6 — block mountains, 7 — borders of the lower-seated terraces of Győr-Komárom

c) Flood Plains of Rivers

The members of the Section studied, on several occasions, the laws governing the composition and the development of the flood plains of rivers. In the course of detailed research work in the Danube Valley, Szilárd (1955), Marosi (1955) and Góczán (1955) made a distinction between a higher early Holocene flood plain horizon and a lower late Holocene one in the flood plain of the lowland Danube Valley (Fig. 6). The deep-seated flood plain horizons — dammed wide pans and cut-off meanders — could be inundated several times a year; they are flooded between the dams even today. On the other hand, the higher flood plain horizons were inundated, before the regulation of the river, only at times of the highest floods. Fine flood silts and calcareous silts were deposited in both the lower and the higher flood plain horizons as described by Szilárd (1955) and Marosi (1955). The higher flood plain horizons are covered with calcareous, loess-like, silty sediments often very similar to the infusion loess. On the initiative of Miháلتz (1950, 1953) we could reliably prove the completely fluvial origin of these formations in the course of field surveys made with him. When studying flood plain horizons and the deposits covering them, additional data were obtained, suggesting that, in the wide, alluvial-fan-like flood plains sediments had accumulated not only by superposition, but also by juxtaposition (Pécsi 1957b, 1959a). By investigating a number of cross-sections from flood plains and terraces we came to the general conclusion that the

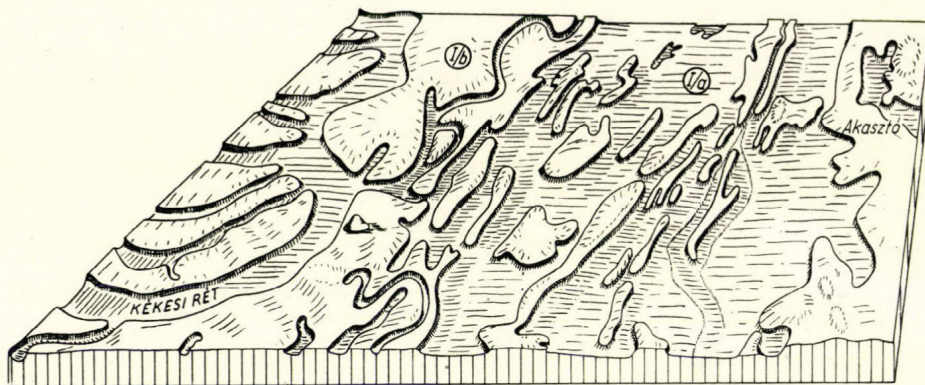


FIG. 6. Position of flood plain horizons in the Great Plain reaches of the Danube, according to J. Szilárd

1/a — Low-seated flood plain, 1/b — high flood plain

depositing activity of the Danube had taken place during the Holocene and even earlier, within the range between the deepest point of the river bed and the highest level of the culminating flood. This means that the coarsest sediments are deposited in the deepest region of the river bed, i.e. along the mean current line, while the mud of the floods constitutes the finest sediments. According to this, in the Holocene the Danube was able to deposit

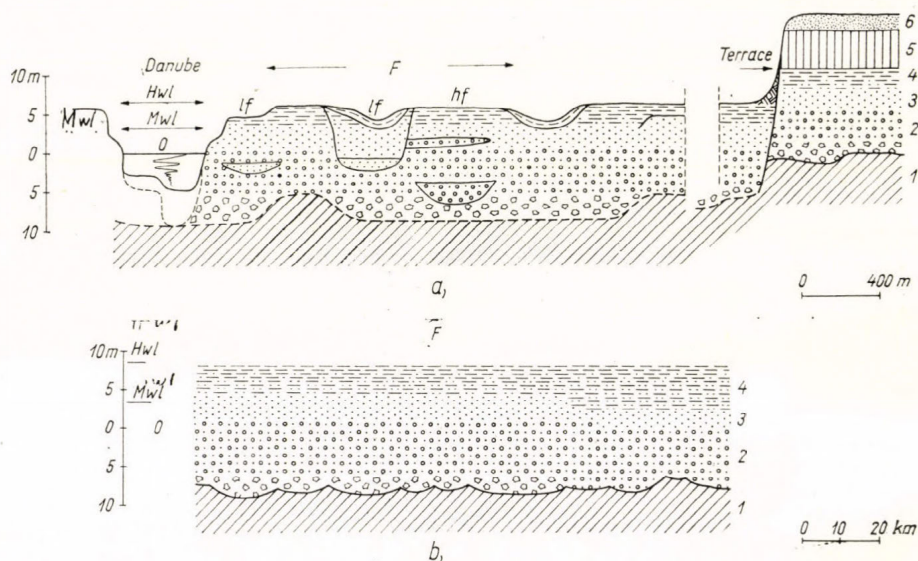


FIG. 7. Structure of the flood plain deposits of the Danube, according to Pécsi

a — Cross-section of the valley sole, b — longitudinal section of the valley sole; 1 — bedrock, 2 — gravelly sediments, the finer the more upwards, 3 — fluvatile sandy silt, 4 — fluvatile sandy silt, silt, occasionally clay, 5 — loess, 6 — blown sand; F — flood plain, lf — low-seated flood plain, hf — high-seated flood plain; HwL — highest water level, MwL — mean water level, 0 — 0 level

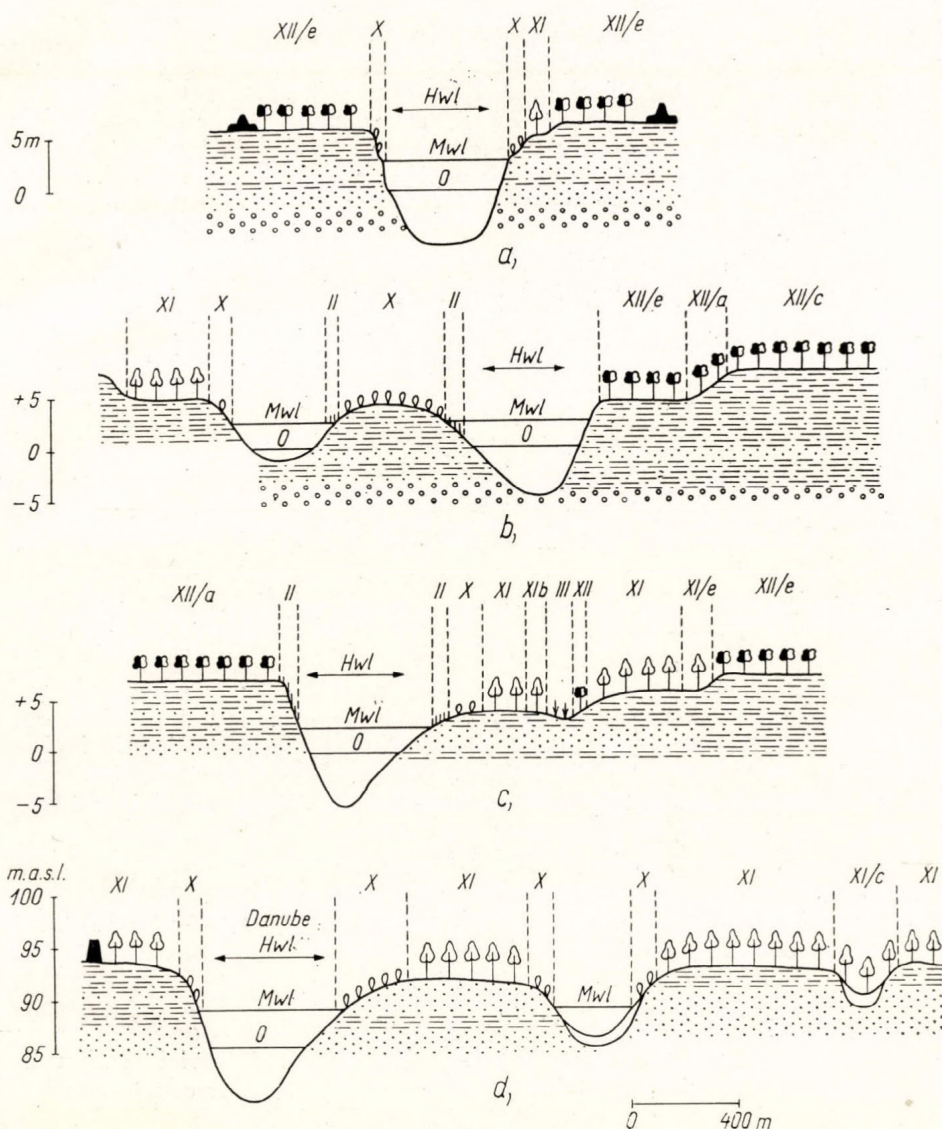


Fig. 8. Principal types of the flood plain horizons along the main channel of the Danube in the Great Plain according to Pécsi and Kárpáti

a — Main channel with almost symmetrical banks, b — flood plain type dissected by a secondary channel, c — flood plain horizons of an extending meander, d — flood plain horizons of the Danube at the landing place at Kalocsa; II — dwarf rushes (*Nanocyperon*), III — reeds (*Scirpeto phragmitetum*), X — willow shrub (*Salicetum triandriae*) along the river bank, XI — willow-poplar grove (*Salicetum albae-fragilis*), XIb — willow-poplar grove (*Salicetum albae-fragilis*) — agrostidetosum sub-association, XIc — willow-poplar grove — sub-association of *Caricetosum acutiformis*, XII — elm-ash-oak grove (*Querceto-Ulmetum hungaricum*), XIIa — elm-ash-oak grove — typical sub-association (normal), XIIc — elm-ash-oak grove — lily-of-the-valley sub-association (*Convallarietosum*), XIIe — elm-ash-oak grove (*Querceto Ulmetum hungaricum*) *Rubosum caesii* facies; Hwl — highest water level, Mwl — mean water level, O — zero level

about 15 to 20 m thick sediments. As a result of the horizontal changes of the river bed, a layer of sediments of such a thickness may be reckoned with, without assuming the sinking of the area (Pécsi 1959a, Fig. 7).

On the youngest alluvial fans of the Danube, the deposits of the higher flood plain horizon may date either from the late Holocene or from the early Holocene or, on the margins, even from the late Pleistocene, depending on the size of the flood plain area turned over affected by more recent changes in the bed of the Danube. We have studied the rate of accretion of flood plain horizons, dead channels and tributaries situated within the dams, and correlated them with plant oecologies (Pécsi 1959a, Kárpáti, Pécsi 1959). A botanist, Kárpáti, helped us in this work. The process of the accretion of flood plain horizons and of dead channels was compared with the effect produced by agriculture during several centuries (Fig. 8).

d) *Erosional Ravines and Gullies*

An important subject of our detailed areal research work was the investigation of the work of soil erosion, the ravines and gullies frequently occurring in the hill countries of Hungary. It has been proved from many points of view that the intensive grooving of the slopes and thus the destruction of the soil are promoted by the ravines and gullies caused by erosion. The rate and trend of their development in relation to relief, the vegetation and quality of the rock were evaluated by Góczán, Marosi and Szilárd (1954) also from a methodological point of view. Ravines and gullies are caused chiefly by linear erosion. On the other hand erosional valleys and dells of complex origin are results of slumps, slope-slides and sheet wash following the incisions by linear erosion (Pécsi 1955a, 1961e, Ádám, Marosi, Szilárd 1959). The evolution of these erosional valleys of complex origin could be evidenced by numerous examples taken from the Danube Valley (Pécsi), and from the Mezőföld and the Transdanubian Hill Country (Ádám, Marosi, Szilárd). The dells of our hill regions, in the formation of which linear erosion no longer plays an important role, was proved to be a very frequent valley type to be discussed later (see Section 4/b).

e) *Mechanism of Fluvial Erosion*

In Hungary studies concerning the mechanism of fluvial erosion have remarkable traditions. Cholnoky's theory on the stream course characters represents pioneer work even in the international literature (1926a, 1926b, 1934). Later on, essays by Bulla (1936, 1941, 1956b) and Kéz (1934, 1935, 1942), dealing with changes in the character of the stream course under the influence of climatic changes, represented a new development in the theoretical research of erosion. The investigations of the hydrogeologist, J. Bogárdi, concerning erosive processes in the river bed, the forms of river beds and the transport of bed load are a fundamental source for geomorphologists (1955, 1958). Kádár (1955—1960) has developed new theories with an aim of defining the processes of fluvial erosion and accumulation more exactly. These theories are useful in the interpretation of forms occurring in the river bed. Never-

theless, like other Hungarian physiographers, we cannot approve of the theory of Kádár according to which the terraced valleys are formed merely as a consequence of the meandering of the river, in the course of the autodynamism of erosion, i.e. without the influence of any tectonic or climatic factor. The physiographic research workers of the GRI naturally also took part in the discussion of Kádár's theories. Here we have to mention the comments of Pécsi (1959a), Bulla, Somogyi and Marosi on the new interpretation of the fluvial erosion and the stream course characters published by Kádár (1960a).

More exact investigations on the climatic and tectonic prerequisites of fluvial erosion and accumulation and an increasing amount of the necessary data helped Somogyi (1960) to outline a synthesis of the evolution of our river drainage, which is much more detailed than any of the preceding attempts. He strived to follow the more persistent changes of the river mechanism according to the rhythm in the morphological development of Hungary since the late Tertiary, explored by Bulla (1954b, 1956a).

INVESTIGATION OF THE PROCESS AND FORMS OF DEFLATION

a) *Formation and Morphology of Blown-Sand Areas*

As a consequence of the teaching of L. Lóczy Sen. (1913, 1918) and especially of J. Cholnoky (1902, 1910, 1937, 1940) the role of the wind, i.e. deflation was exaggerated. A desert climate was supposed to have prevailed at the end of the Pliocene and the considerable denudation of the Pannonian surface, particularly in Transdanubia, the cutting out of longitudinal valleys and the origin of a number of other forms were ascribed to the activity of the wind. Subsequent investigations (Szádeczky-Kardoss 1938, Bulla 1941, Kéz 1937, Sümeghy 1939, 1951) proved the desert-deflation theory of Lóczy and Cholnoky to be faulty. The pillars of Lóczy's and Cholnoky's desert-deflation theory fell down. It was undoubtedly correct to refute the theory according to which desert climate prevailed at the end of the Pliocene and the theory of surface-shaping deflation, but the reaction to them, under-rating the surface-modelling role of deflation in Hungary, was similarly exaggerated. This explains why the attention of most physiographers was riveted on the examination of fluvial erosion and why the destructive forms and the accumulated deposits were considered to be mostly of a fluvatile origin. Finally, this attitude led to such extreme views as e.g. that of Kádár who explained the accretion of lowlands, the formation of the characteristic lines of the river drainage and terraces simply by the surface-modelling effect of erosion and rejected the theories attributing a certain role also to the crustal movements or to the climatic changes. We can say now that the endless debates on this topic have certainly diverted the research workers' attention from the study of the surface-modelling role of other external agents.

However, in recent years, thanks to the results of our research, the various forces shaping the surface of the earth have been assessed more and more according to their real importance, and their functions have been examined by considering their total effect.

It has been proved during our investigations that many phenomena and forms ascribed by Cholnoky to desert deflation at the end of the Pliocene were in fact due to it, yet deflation cannot be limited to the end of the Pliocene; it should rather be related to the deflation of the cold-dry climate of glaciation. The angular gravels which can be found in many places on the surface of our Pleistocene terraces and alluvial fans show an intensive activity of deflation under periglacial climate (Pécsi 1959a, 1961e). Accordingly, we must, by all means, reckon with the modelling effects of the periglacial deflation in the plains, hill countries and highlands of Hungary.

Our blown-sand areas have also proved to be considerably younger. The now existing blown-sand features are particularly young: Late Pleistocene and Holocene (Bulla 1960, 1953, 1951, Marosi 1953, 1955, 1958). We have to emphasize the recently recognized fact that the great majority of features occurring in our blown-sand areas are due to the work of the wind moulding the sand material of the alluvial cones and of the terrace surfaces. However,



FIG. 9. "Slope loess" with veinlets of gravelly detritus and solifluctional clay lumps. Pilisvörösvár fault trough, brickyard near Budapest. In certain strata the material exposed is so detritic as to be taken for loessy-slope debris. Some pockets are loess-like, finely stratified and intercalated by gravel and stone pieces and thin horizons of detritus

the bulk of blown sand has not been transported to longer distances either in the area of the Kiskunság (Bulla 1951, Sümeghy 1951, Marosi 1955, 1958, Szilárd 1955, Pécsi 1957*b*, 1959*a*, 1960*b*, 1960*d*) or in Southern Mezőföld (Marosi 1953) or in the area of Inner Somogy (Marosi 1958, 1960, 1962*a*). Kádár (1956*b*) and Borsy (1961) agree with Bulla (1953) and Marosi (1955, 1958) concerning this question.

The formation of blown-sand features has already been studied by Cholnoky (1902) who recognized the regularities of sand movement. He described the wind-blown furrows, the mounds and the residual ridges characteristic of our areas covered by half-bound sands. Cholnoky's interpretation of sand movement was improved by Kádár (1935, 1938, 1954a, 1956b) who described the Lybian type dunes (1935), the parabolic dunes (1938, 1954a) and the marginal dunes (1956b) as new Hungarian sand features.

The slightly undulated, half-bound blown-sand areas, appropriately named by Bulla (1951, 1953) sheet sands, are very extensive. Marosi (1958) described the so-called longitudinal blown-out dune as a new form of accumulation



FIG. 10. Stratified slope loess slightly affected by cryoturbation, solifluction and (pluvionivation) exposed in the brickyard at Zalaölvő

of the half-bound sands, substituting it for Kádár's Lybian dune who believed that no unbound sand forms occur in the Hungarian sand areas (1956a, 1957) and, at the same time, he found a genetic relationship between the formation of wind-blown furrows, mounds, longitudinal blown-out dunes and sheet sands (Marosi 1958).

b) *Investigation of Loesses and Loess Morphology in Hungary*

Hungarian loess research can rely on a well established basis. In his earlier studies, Bulla (1933, 1934, 1936, 1937—38) expounded his views concerning the formation, composition and forms of loesses to be found in the Carpathian Basin. For his studies he used the data of the international literature and the

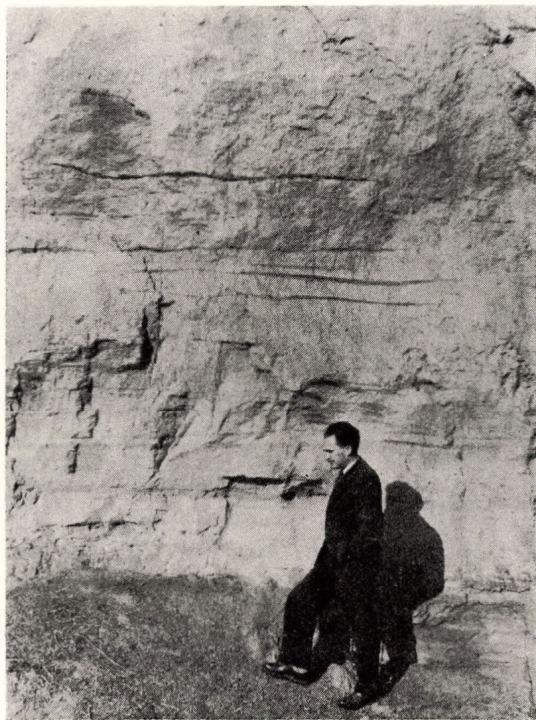


FIG. 11. Bedded slope loess loam affected by pluvionivation and solifluction. Observable on the slope as well as under the sole of the wide derasion valley (dell, *vallée en berceau*) filled up thickly with this formation

mapping of the plains. These data served as a basis for further analytic work results of his own investigations; he ranged the Hungarian loesses into the category of those formed from subaerial dusts during the cold-dry glaciations. He accomplished the chronologic subdivision of loesses by using the chronology of the river terraces and the fossil soils.

In recent years studies on the morphology and genesis of loesses have completed and modified the results of earlier investigations in many respects.

Many data were collected, especially in the course of the detailed geological (Sümegehy, Miháltz, Kádár, Bulla, Kriván, Mihályi, Lányi). In the course of our studies we have published more and more data ascertaining that Hungarian loesses are not of eolian origin. An ever-increasing number of loess varieties could be proved to be products of fluvial (Miháltz 1950, 1953, Marosi 1955, Szilárd 1955, Kádár 1954*b*, 1960*a*) or of eluvial and deluvial processes (Pécsi 1961*c*, 1961*e*). In the course of heated debates, even within our Section, as to the origin of certain loess varieties, it became clear that loess of eolian origin occurs, in its original emplacement, only in smaller areas. Attention has been called to sand layers, frequently intercalated in the loesses, by the investigators of the Mezőföld (Ádám, Marosi, Szilárd) who consider them to be chiefly of fluvial origin.

We have observed during the last two years that hillside loesses, loess-like sediments, sandy loesses and sands showing a fine stratification parallel to the slope cover large areas. It has been ascertained that the redeposition of these formations is due partly to pluvionivational and partly to solifluctional movement proceeding along the slope, for the most part, still under the influence of periglacial processes (Pécsi 1961*e*, 1962*a, f*). We could separate, in this way, hillside loesses of different composition spread on a regional scale in Hungary (Figs 9, 10, 11). In recent years the detailed examination of loesses has likewise permitted us to undertake the regional mapping of fluvial loess silts lying at the flood plain level or a few metres higher and occupying vast territories in Hungary. The loess-like rocks of fluvial origin could be subdivided into Holocene and Pleistocene loessy silts (Marosi 1955, Pécsi 1961*d, e*). We attached the type of the sandy loess mantle covering the sand dunes of our blown-sand areas in a thickness of 1–2 m to the category of the dry superficial loesses; however, after studying the exposures they were correlated with the process of soil formation (Kádár 1960*b*, Pécsi 1961*e*), in accordance with Berg's theory. On the basis of the results of the investigations carried out so far, we were the first to make an attempt to represent the Hungarian loesses and loess-like formations of different habitus and genesis in the form of a map (Fig. 12).

The microfeatures of the Hungarian loess reliefs, their distribution and genesis have been dealt with by Ádám, Marosi, and Szilárd (1959), when investigating the loesses of the Mezőföld and the Transdanubian Hill Country. Ádám (1954), analysed in detail the loess valleys of the Mezőföld, the genesis of which he ascribed, first of all, to the karsting of loess, although he took slump and slope wash also into account. Szilárd drew attention to the dialectic relationships between the areal erosion and derasion processes and the processes of linear erosion. He has proved that the transformation of flat initial valley sections into narrower and deeper ones is due to the quantitative changes of the erosive action under the influence of an increase in the amount of water and in the slope angle, turning, beyond a certain limit, into qualitative changes. Marosi studied the erosional ravines and gullies of the loess surfaces, the laws of their development and the destruction of soils and grounds caused by Holocene shower waters. The experience of these authors proves that such forms have mostly developed during the Holocene period. The loess-morphological studies of the members of the Section have yielded numerous

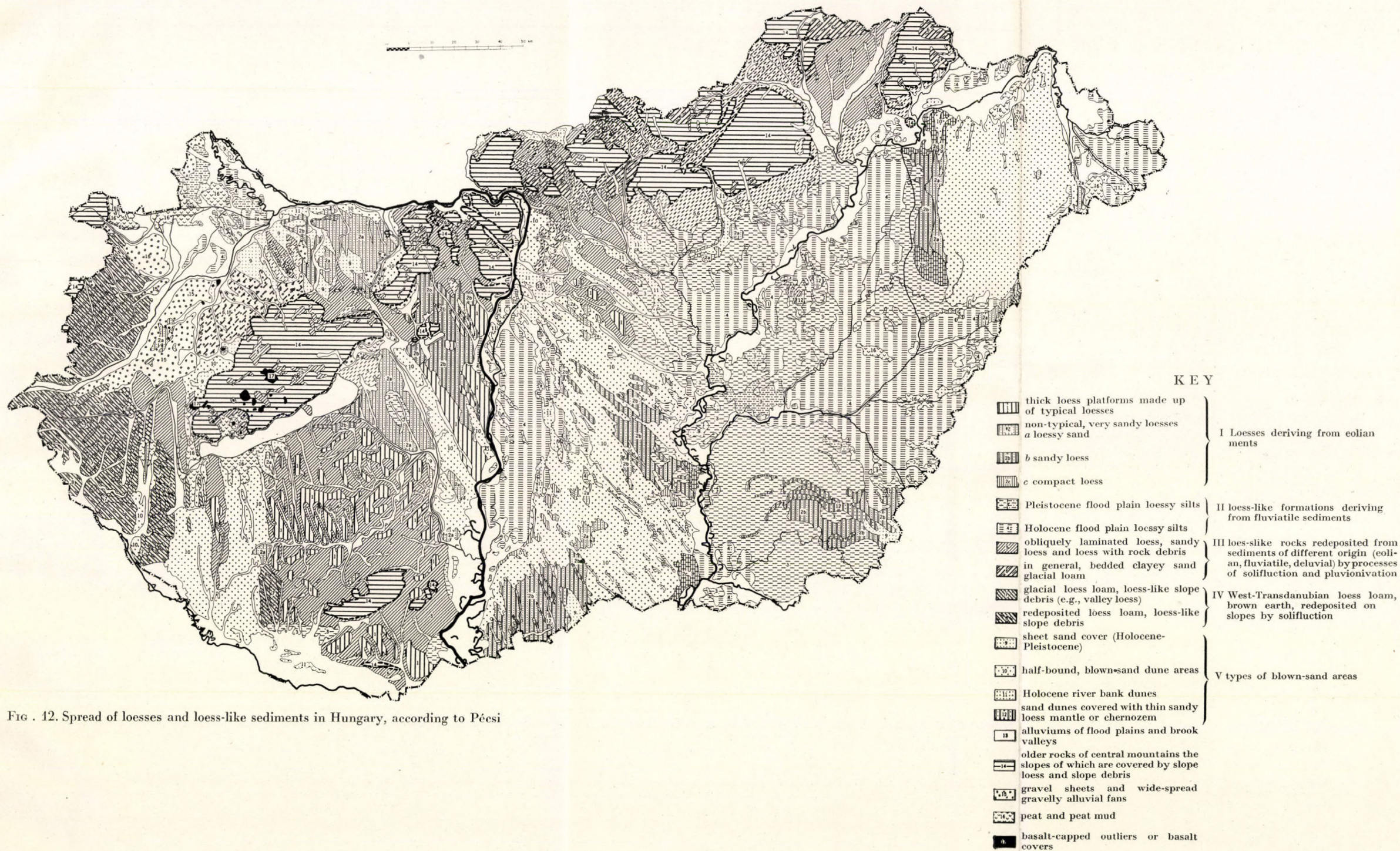


FIG. 12. Spread of loesses and loess-like sediments in Hungary, according to Pécsi

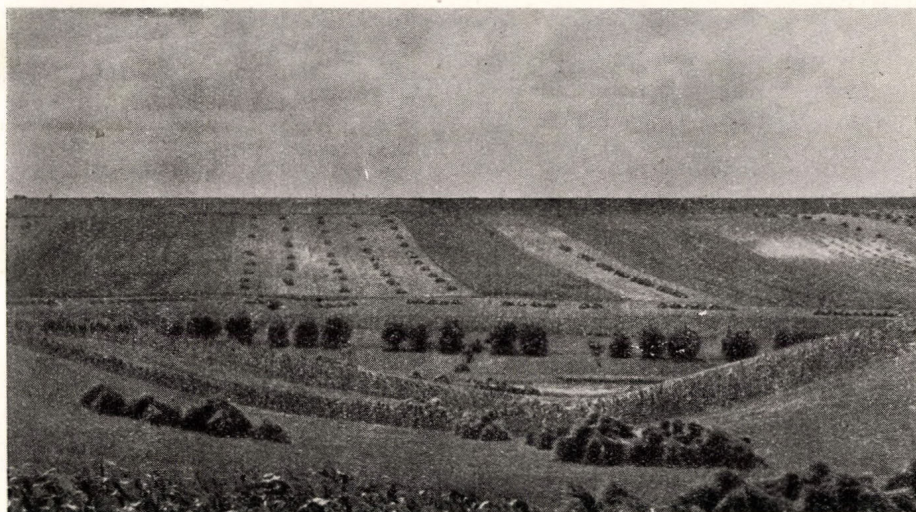


FIG. 13. Wide, erosion-derasion valley on loess platform. Mezőföld (Photo E. Vajda)



FIG. 14. Loess valley intersected by Z-shaped breaks. Loess platform of the Mezőföld

data for the classification of the Hungarian loess varieties, for the interpretation of their genesis and the characterization of their form wealth (Figs 13, 14).

CHRONOLOGICAL PROBLEMS OF THE QUATERNARY

The chronology of the Pleistocene deposits is one of the most important theoretical questions of the research into the Quaternary in Hungary as well as abroad. In the Pleistocene periglacial areas the subdivision is generally based upon the stratigraphy of the loess and terrace sediments, completed by speleological and archaeological investigations. Hungarian morphologists, as well as the members of the Section, based the chronological subdivision of the Pleistocene on the parallel stratigraphy of loesses and terraces. Bulla's relevant earlier studies have served, in this connection too, as a basis.

The Hungarian loess chronology is based chiefly on the number of fossil soil layers present in the loess, following the principle that the buried soils are remnants of the warmer and more humid forestial climate of the interglacial and interstadial periods, while the loess sequences in question represent an evidence of the dry-cold steppe climate of the glaciations (Bulla 1937—38). According to this, all the loam zones found in any exposure of loess would represent either interglacials or interstadials. This method of chronological subdivision has been and is still dominating the morphological literature in such a way that the above-mentioned fossil soil zones have been fitted into the corresponding scale of Penck—Soergel's Pleistocene chronology and then into that of Milanković—Bacsák. Bulla adopted this theory when he gave first (1933) the chronological order of the series exposed at Paks (Figs 15, 16). According to this, the Paks loess wall represents the whole Pliocene series of Hungary. Ádám, Marosi and Szilárd (1959) who had subjected the Paks exposure to a detailed analysis obtained similar results. However, while subdividing the loess series, Ádám took into consideration as a new point of view also the sand layers, which he regarded as fluvial deposits "lying horizontally" and dissecting the loess. He presumed the sand horizons to be, in principle, an evidence of periods of erosion, i.e. remnants of interglacial-interstadial climatic types. It is by all means right to consider the intermediary sand horizons in the division of loesses but Ádám only accomplished the chronological identification of a single, but most important, sand sequence.

The chronological division of the loess exposure of the Paks brickworks was discussed in greatest detail by P. Kriván (1955). He largely contributed to the chronological division of the Paks loess wall by developing a new approach based on the succession of loess pockets which had been deposited on dry land surface. He only partly took into consideration the fossil soil horizons present in the exposure. The process of soil formation was held by him for posterior changes rather than for diagenesis.

According to Kriván, the loess exposure at Paks would include an almost complete series of the Mindel Riss and Würm glaciations, and he considered

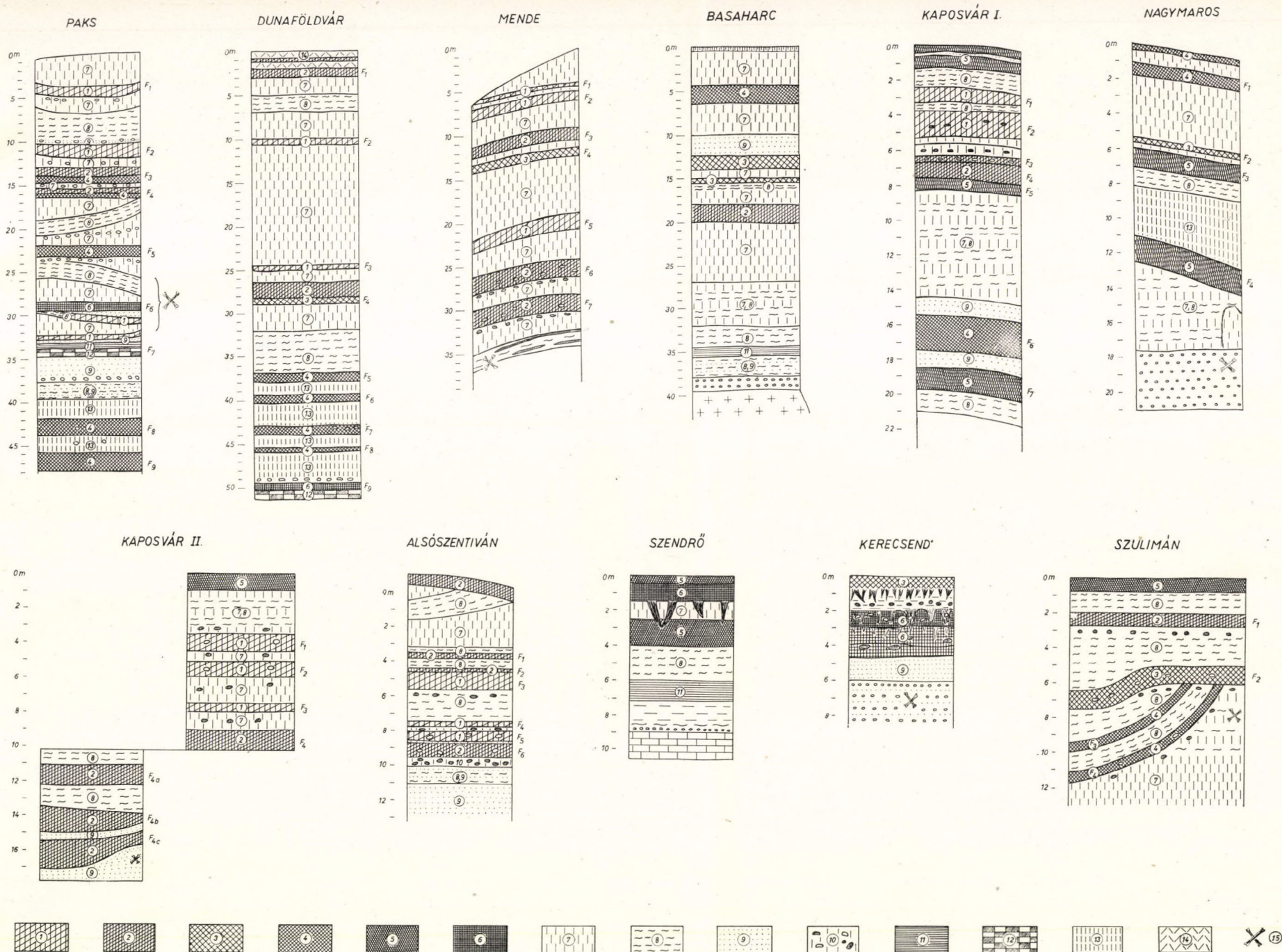


Fig. 15. Most important loess exposure of Hungary:

1 — poorly developed soil, humus carbonate soil with molehills, 2 — soils of chernozem nature, 3 — brown forest soils of chernozem dynamism, 4 — brown forest soils (*Braunerde*), 5 — clayey brown forest soil (*Parabraunerde*), 6 — red soils, red clays, 7 — unstratified loesses, typical and sandy loesses (aeolian loesses), 8 — stratified hillside loess and loam (affected by solifluction and pluvionivation; deluvium), 9 — stratified sand, loessy sand, 10 — molehills, animal tracks, 11 — boggy soil, 12 — lime stone concretion — loamy loess, 14 — strata affected by human activity, artificial accretion, 15 — fossiliferous locality;

FOSSIL FINDINGS

Paks brickyard:

Mende brickyard:

Basaharc brickyard:

Nagyamaros:

Kaposvár brickyard:

Kerecsend:

Suliman brickyard:

Coelodontatis, *antiquitatis* Equus sp. (Würm type), Elephas sp., Cervus sp., Bos or Bison sp., Rangifer tarandus, Leo speleus (determination by Dr. M. Kretzoi)

Equus sp. (Würm type), Elephas sp. (determination by Dr. Mr. Ketzoi)

(after M. Mottl) Mammuthus primigenius, Cervus elaphus, Megaloceros giganteus, Leo speleus, Rupicapra rupicapra, Ochtona sp., Marmota primigenius, Coelodonta antiquitatis

Coelodonta antiquitatis, Bison priscus, Cervus elaphus, Rangifer tarandus, Alces alces, Coelodonta antiquitatis

Coelodonta antiquitatis

Microtus gregalis (345 specimens), Salamandra sp. (1 specimen), Rana temporaria (abundant), Rana arvalis (3 specimens), Lacerta viridis (3 specimens), Coturnix coturnix (2 specimens), Sorex araneus (4 specimens), Talpa europaea (1 specimen), Citellus citellus (14 specimens), Siscia betulina (9 specimens) (The fossils are dated by Dr. M. Kretzoi to the Würm)

this exposure to be the most suitable for the solution of Quaternary stratigraphic problems of Central Europe, regarding it as a type section. Although he emphasized that his investigations did not aim at substantiating Milanković—Bacsák's or anyone else's absolute chronology and that he only compared the palaeoclimatologic changes of beds with it, his division has still not proved to be independent of the afore-mentioned scheme. While treating the succession in the sedimentation of the loess wall and in the series of events involved, he did not take into account the loess pockets accumulated on the slope by



Fig. 16. Loess exposure at Paks. The longitudinal section shows the longitudinal axis of a buried dell. The buried soils dip towards the wall in a flat arc and are intercalated by thick-bedded slope loesses

solifluction, the formation of blind creeks and their re-filling. In addition, he did not reconstruct the climatic conditions corresponding to the types of fossil soils in the exposure and did not pay them proper attention in establishing his chronological division. Nevertheless, he deserves credit for having thoroughly analysed the lithology of the exposure and for having performed its evaluation.

Naturally, the chronological subdivision of our loesses highly depends on how many "inter"-epochs are included in the last glaciation, and in each particular glaciation. In Hungary the last glaciation is generally split into three periods by two interstadials. However, the data available at present, the number of which has rapidly increased in recent years, have proved the presence of more than two, in fact of four or five, fossil soil zones within loesses dating from the last glaciation (Pécsi 1961*e*, 1962*b*). Data to the above statement have been furnished by the loess exposures of Basaharc and Nagymaros

having four to five loam zones overlying the second flood-free terrace, as well as by exposures where, in the beds underlying the third to fifth fossil soil zones, a fauna dating from Würm glaciation has been found (Fig. 15). Among the buried soils dating from the last glaciation, beside brown forest soil, also soil types of chernozem character and chernozem brown forest soils could recently be evidenced in a number of places. Moreover, also

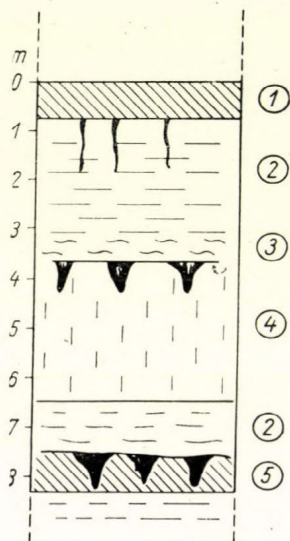


FIG. 17. Generalized section of the sloping strata between two buried soil zones

1 — Fossil chernozem soil or chernozem brown forest soil, 2 — finely bedded slope loess redeposited by pluvioniviation; in the upper part the cracks are filled with lime or fossil soil, 3 — slope loess slightly affected by cryoturbation and redeposited by solifluction; small ice wedges penetrate from the lower part of the layer into the underlying loess, 4 — unstratified loess packet, 5 — buried fossil soil with frost phenomena

red soil horizons occur. In addition there also appears a light chestnut-brown, cloddy fossil soil of chernozem character containing many mole hills, but few clay minerals. The typology of this soil and the climatic conditions of its formation are not yet clarified. These soil types, themselves, testify to the periodic change of four to five different types of climate during the last glaciation. The Pleistocene climate types of Central Europe were recently characterized in detail by Bulla (1960) and Somogyi (1961, 1962b), too.

However, since more than two buried soil horizons can be detected within the Würm Glaciation, the climatic types favouring soil formation recur several times and it will probably be possible to interpret them as "microinterstadials" in the last glaciation climate of Hungary. Nevertheless, it may also be presumed that, for instance, the above characterized dry steppe-type soil and the humus carbonate soils might also have been formed in loess under one of the drier and colder periglacial climates (cf. the soil types developed under the colder and drier climate of Mongolia and Siberia).

In the course of a renewed study of the most important loess outcrops in Hungary (Fig. 15) we have found, in addition the unbedded loess and the fossil soil sequences claiming for various climates, the stratified loess horizons exhibiting patterns of pluvioniviation and solifluction as well as the phenomena of cryoturbation to be suitable for the subdivision of loesses (Fig. 17)

Besides this, we also considered the relation of the loess sequence to the terraces and the possible faunistic and archaeologic findings. All these together may serve as a basis for the chronological division of the Hungarian loesses. When evaluating the loess profiles already studied in this respect, it should be stated that, in Hungary, the presence of pre-Würm loess strata can be suggested only for the exposures of the Paks and Kaposvár brickworks (Fig. 15).

Our terrace-morphological observations have provided data on the chronology of the Quaternary which have shown, like those furnished by the studies on loesses, that the older alluvial fan terraces at Pestlőrinc and

Rákoskeresztúr, ranked previously as the upper Pliocene, are younger and belong to the Pleistocene (Pécsi 1956c, 1958a). An important aid to determine the age of our oldest Pleistocene terraces was the detailed investigation of cryoturbation and the analysis of the roundness of gravels. The information obtained in this way has permitted us to ascertain that the lower boundary of the Hungarian Pleistocene must be drawn long before the Günz glaciation as the formation of its terrace VI above the flood plain of the Danube and the Dráva, and in certain Austrian reaches its terrace VII too, as well as the deposition of the material of the alluvial fans of the Kemeneshát and Parndorf can be dated from the beginning of the Pleistocene, i.e. from Günz—pre-Günz glaciations (Pécsi 1959a, 1960d, Somogyi 1960). The gravels occurring in the Mór fault trough (Ádám 1959a, 1959b) and those in Billege (Góczán 1960a) have similarly proved to date from the early Pleistocene. Our studies on terrace morphology have helped to collect regionally new data for drawing the boundary between the Pliocene and the Pleistocene. These data support and complete the relevant investigation of Szádeczky-Kardoss, Bulla, Sümeghy and Kretzói. The lower boundary of the Pleistocene — on the borders of basins — can be drawn in the sequence of commonly coarser-grained sandy gravels overlying with unconformity the sandy fluvio-lacustrine deposits of the upper Pliocene.

THE ROLE OF DERASION¹ IN THE MODELLING OF THE EARTH'S SURFACE

a) Slope Deposits Affected by Gelisolifluction and Pluvionivation²

In exposures situated on the slopes bordering the Hungarian hill landscapes and mountains, widespread deposits with a bedding parallel to the slope could be recognized (Pécsi 1961c, e). Fine bedding roughly corresponding to the angle of the slope could be detected not only in slope loesses and loamy sediments, but also in rock mixtures of various particle sizes, consisting of clay,

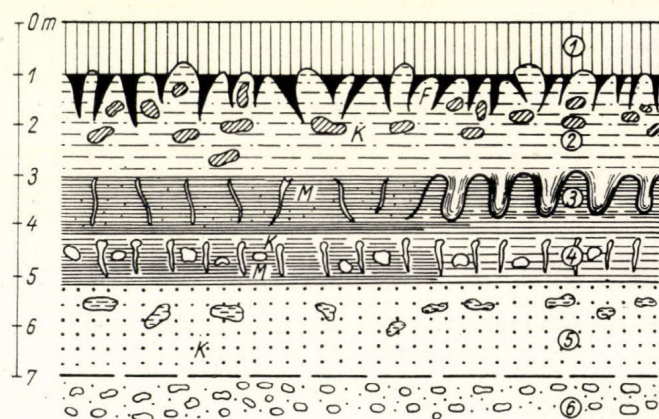


Fig. 18. Slope accumulation by rhythmical solifluction (Kerecsend)

Layers 5 and 6 represent alluvial formations dating from the end of Riss and from Riss—Würm interglacial (with *Coelondonta antiquitatis*); their upper horizon was deposited by pluvionivation. Later, in the more rainy Riss—Würm interglacial period, the Laskó Brook cut a wide and rather deep valley into the alluvial fan. A drier, cold period of Riss—Würm formed a red clayey soil (first phase of soil formation) which, during the earlier Würm glaciation, was redeposited on the slope by solifluction. Layer 4 assumed its present position in that time; in a warmer period, animal burrows (*krotovina*) formed in it and in the underlying layer. Later on, small dessication fissures and frost clefts appeared on the surface. The brownish-red layer 3 was deposited by solifluction in a subsequent humid-cold phase. Again, in a drier, cold period, probably during Würm Glaciation s. str., the areal solifluction developed into a striped, grooved solifluction process which brought about sheaf-like deepening in the red-brown clayey-sandy loam. A gradual redeposition of rock material by areal solifluction, in turn, resulted in the formation of the sandy-limy loam 2. On this horizon, a new soil was set (second phase of soil formation) — the brown forest soil 1 — which developed into chernozem during a transition into a dry-cold, frosty climate. In one of the still colder dry periods of the end of Würm, tiny pectinate wedges of 0.4 to 0.5 m diameter (*F*) made their appearance in the chernozem; *M* — frost veinlets filled with lime, *K* — molehills

¹ Derasion is understood to mean the common effect of gelisolifluction, cryoturbation, pluvionivation, cryofraction and gravitational movements under periglacial conditions.

² Pluvionivation is used to denote the degradation of slopes by snow melt and sheet water under periglacial conditions.

loam, loess, foess-like sediment, sand, shale, gravel and loamy rock debris. It is characteristic of the position of these sediments that they cover the slopes as a mantle in the foreland of our hill and mountainous regions, adjusting themselves to the present relief and following its configuration. Sediments

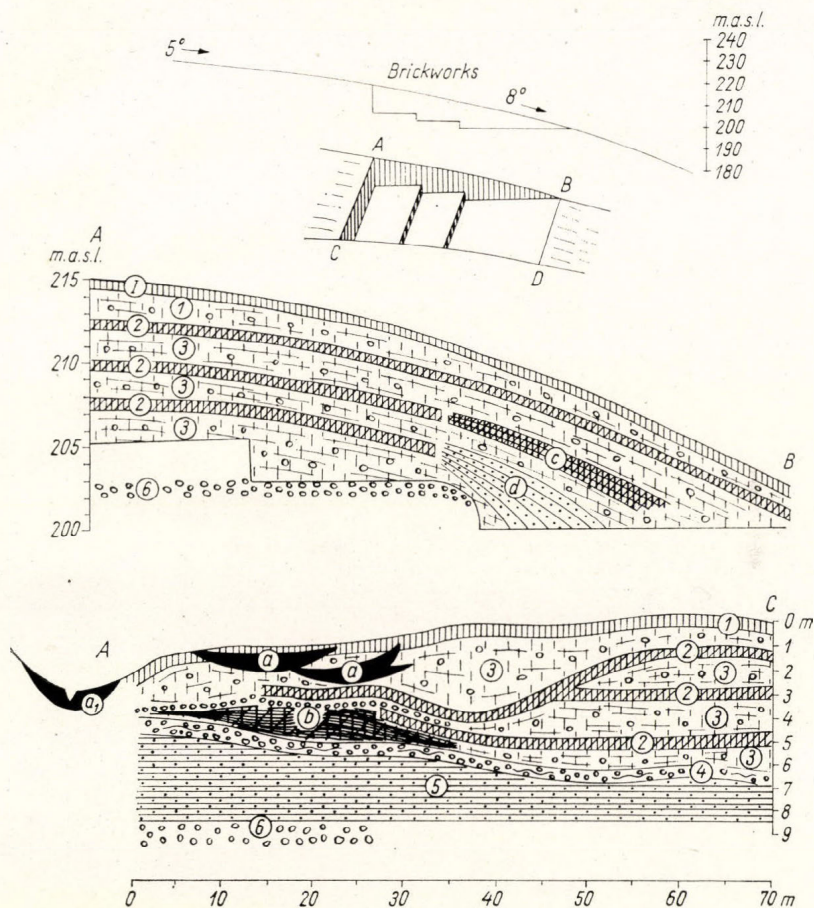


Fig. 19. Accumulation of slope sediments by solifluction and pluvioniviation. Brickworks at Zalalövő

The cross-section reveals some small buried dells. The smaller dells are filled with thin-bedded, red-brown soil (*a*). The larger, middle dell is filled with thin-bedded, brownish-yellow loess-like loam (3). From the right side of the exposure, three fossil, pseudogley soil zones (2) proceed towards the middle dell where they unite in one fossil soil underlain by a thin layer of solifluction gravels. Below the latter lies an amorphous bed of fossil soil material, also redeposited by solifluction (*b*). The whole section is crossed by a solifluctional gravel bed 10 to 50 cm thick, mixed with clay (4), representing one wing of a former dell. The thin-bedded, loess-like, sandy clay (5) is underlain by the lower Würm terrace gravels II/b, of the Zala River (6). 1 — truncated section of the clayey brown forest soil; 1 — brownish-yellow, loess-like loam of hardly visible stratification; the loam is interspersed with quartz grains redeposited from a higher terrace horizon; *a*) 1 — more recent, partially filled dell which is now incised by ravines and gullies, *c* — thin layers (several cm thick) rhythmically redeposited from fossil soils, *d* — thin sandy clay, sand and loam layers deformed also by frost, with a steep dip at the face of the terrace

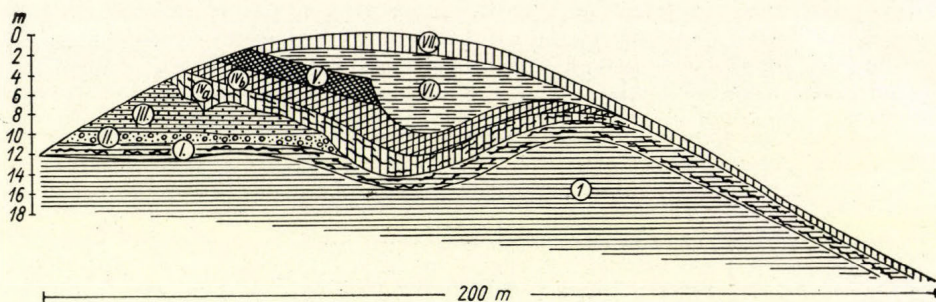


FIG. 20. Dell filled with amorphous solifluction material. (Eger, brickyard in Noszvaji Street)

1 — Oligocene clay; I — Oligocene clay affected by solifluction and frost deformation, II — sand, shale debris, gravel of local origin, remnants of an erosive period, III — finely stratified, laminated solifluction clay and fine-grained sandy clay, once subjected to frost deformation, IV — filling material of the dell; *a* — dark red-brown, oamy, amorphous material deriving from a clayey brown forest soil redeposited by solifluction, *b* — thin bed, (several cm thick) of red-brown, fossil soil lumps; V — rusty brown, loamy soil (*lessivé*), VI — solifluction loam redeposited after a further dell was formed, VII — horizon B of red-brown, fossil (*lessivé*) clayey forest soil. After the dell was filled, a surface inversion took place

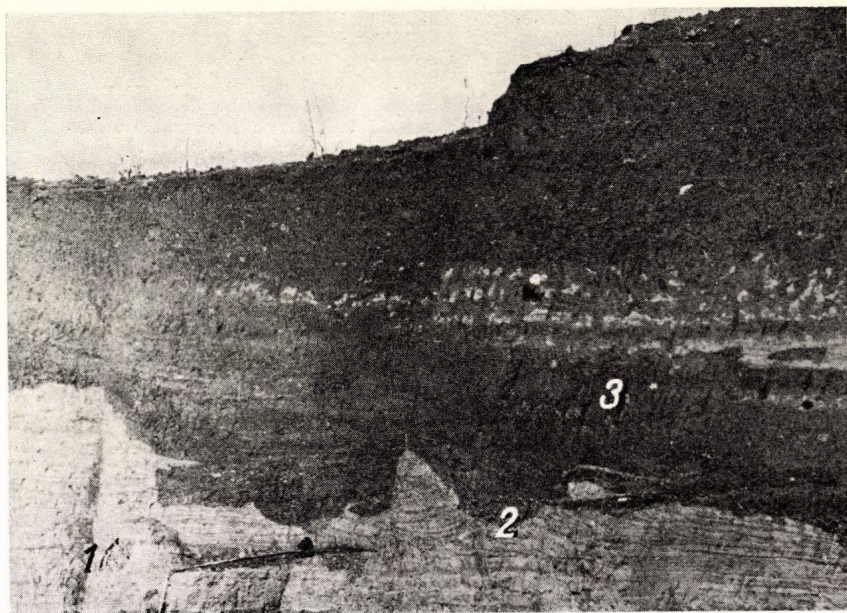


FIG. 21. Type of sediment accumulation by rhythmical solifluction. (Brickyard in Noszvaji Street, Eger)

The thin alternating varves of clay, sandy clay and clayey sand, visible in the lower half of the picture (1), follow the present-day dip of the surface. The surface of this peculiar *Bänderton*-like (varved clay-like) material, accumulated by laminar solifluction, was degraded by subsequent erosion which is evidenced by the presence of gravels and grits on the surface of the sediments (2). Then after an erosive discordancy, there followed a series of brown loam several metres thick redeposited in an amorphous state by solifluction from the horizon "B" of the clayey brown forest soil (3).

of this type can also be observed in filled-up dells. Since sediments of extremely varied granulometric composition and with a bedding parallel to the slope show a dip of $1.5-30^\circ$, and since their thickness even reaches 20 m, their origin cannot be explained by fluvial or eolian accumulation. The formation of sediments stratified parallel to the slope was attributed by Pécsi, in the case

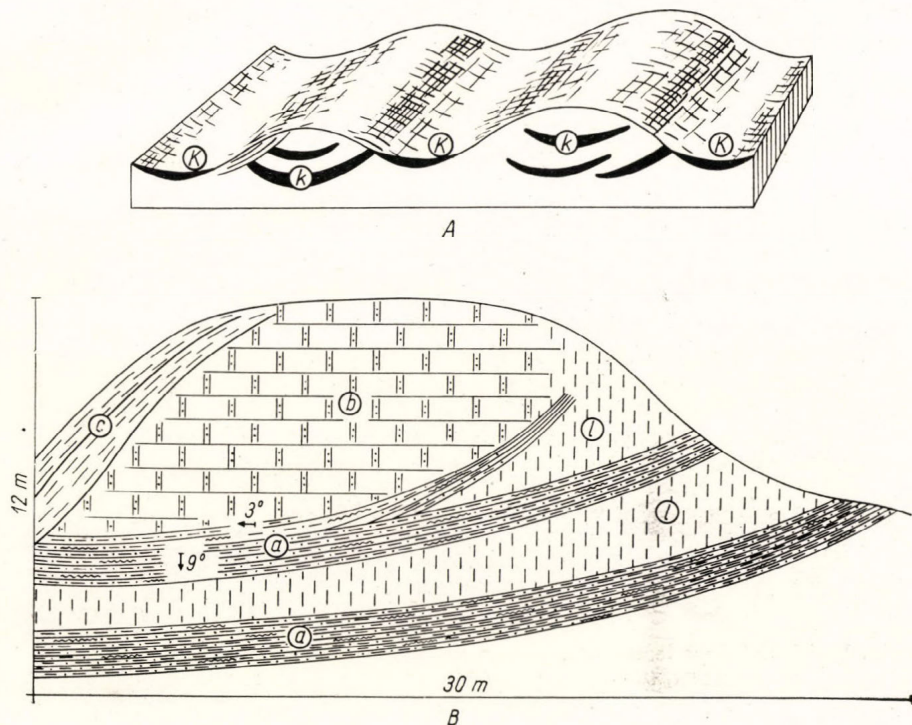


FIG. 22. Slope loess in the filling material of ancient dells.
(Brickworks of Tolnanémedi)

A) *K* — Dells issuing upon the present day sole of the Kapos River; on their basement there are 1–2 buried chernozem soil horizons with Neolithic findings, *k* — well discernible traces of ancient, buried dells, B) *a* — densely bedded (0.5 to 1 cm thick bands) fine sand and silt fraction with minute undulating curls, *b* — slightly bedded, nearly horizontal loess-like rock interrupted by sands, *c* — slope loess with a scarcely visible bedding and a very steep dip; *l* — slope loess seemingly unbedded

of clayey-loamy rocks, to solifluction proceeding along the slope, while in that of loessy and sandy rocks, to the redeposition of sediments by pluvionivation. He emphasized that, under climates of the periglacial type, slopes were formed principally by solifluction, pluvionivation and gravitational movements (see Pécsi 1961*b, c, e* and 1962*f*) (Figs 18–30). In the dry-cold climate of the periglacial periods, gelisolifluction caused by regelation, the denudation by pluvionivation of slopes proceeding on permanently or periodically frozen soils and deflation resulted in: 1. The removing of the rock material, making thus the steeper portions of mountain and hill more gently sloping; 2. The

accumulation valleys of large masses of sediments at the base of the slopes and at the bottom of valleys. Slopes had been covered by a mantle of deposits generally thickening downwards owing to derasion (Pécsi 1961e, 1962f).

Under the influence of periglacial slope processes, a considerable part of the soils formed in the preglacial and the interglacials was redeposited by solifluction and pluvionivation in the meantime mixing with rough mineral material, slope loess, loam and sand. Such stratified slope deposits affected by derasion

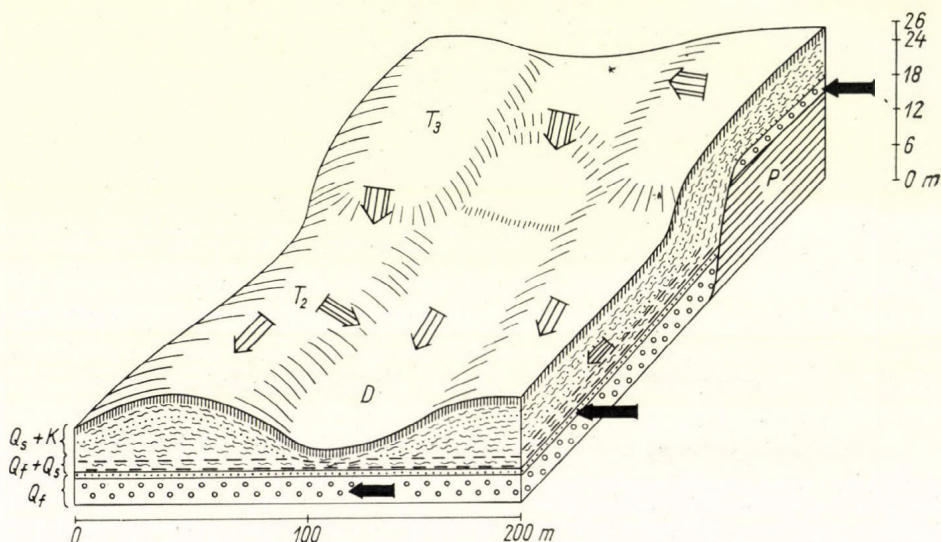


FIG. 23. Position of slope loesses and loose sediments in relation to fluvial terraces

The dark arrows indicate the fluvial transportation of sediments, the light ones the derasive transportation. Q_f — Pleistocene fluvial sediments, $Q_f + Q_s$ — alternating fluvial and solifluction sediments accumulated during the Pleistocene, $Q_s + K$ — accumulation of sediments by solifluction and pluvionivation during the Pleistocene, T_1, T_2, T_3 — second and third flood-safe terraces with overlying slope sediments, D — deli, P — Pannonian layers

contain, in places, many fossil soil particles and alternate on the slopes with loess and buried soil layers. This bedrock was the source of the soil formation of the Holocene epoch in the hill regions of Hungary. This peculiarity of our slope sediments creates very advantageous conditions for agricultural production since the superimposed buried soils and the redeposited sediments mixed with the humus material of former soils may also have important nutritive properties. This structure of the slope deposits makes the erosion of soils slower; but even if soil erosion destroys the present fertile soil, the buried soils and the slope sediments mixed with fossil soil clods (semipedolites) will continue to provide a certain fertility (Figs 21, 31—33).

The results of our investigations suggest that the whole territory of Hungary belonged to the realm of the periglacial climatic morphology. Consequently, the modelling of the surface during the glaciations considerably differed from the normal fluvial erosion of the preglacial times and of the interglacial

periods. Whereas, under the influence of the climatic processes characteristic of the temperate zone, valley formation was predominant, during the glaciations the morphological processes of the semiarid periglacial climate caused areal denudation, over-all slope wash, the formation of slope deposits and the accretion of the valleys. Normal erosion lost its primary importance in modelling, and freezing as well as the movement of sediment along the slope on frozen

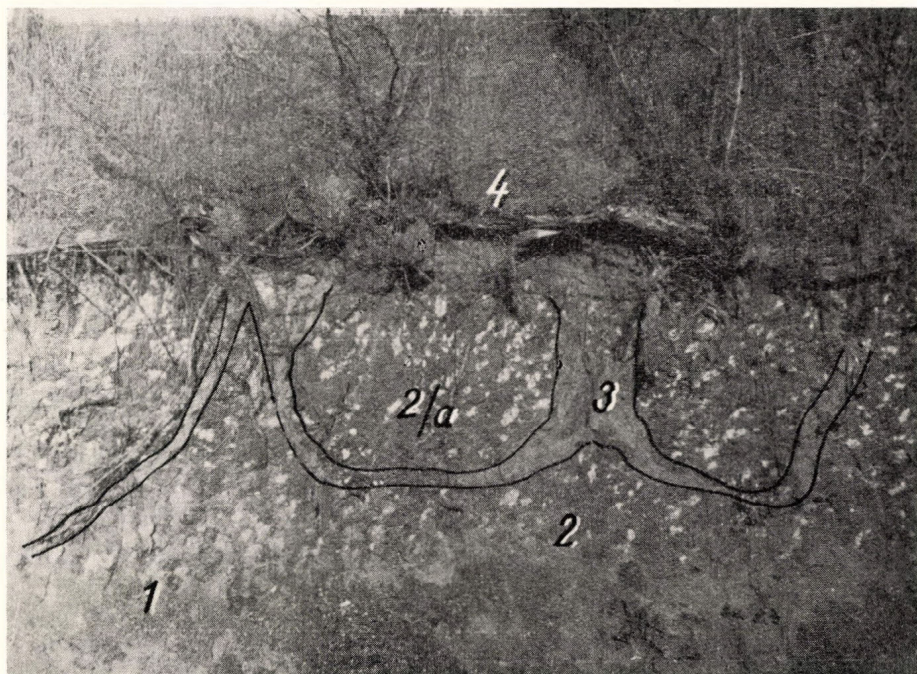


FIG. 24. Banded, furrowed, cloddy red clay soil on gentle slope (*Streifenboden*) of a derasion hillock protruding from the Tolna Ridge (Belecska Village)

The base of the exposure is Pannonian clay (1) overlain by red clay 1 to 2 m thick, containing limestone nodules (2); the banded, furrowed, cloddy soil (striated soil); 2/a) formed within this layer intersected by sand veinlets (3). The surface is covered with blown sands (4)

ground, as a consequence of the common effect of regelation and gravitational movements, became principal agents; deflation and the accumulating activity of the wind played periodically and in places an equally important part in the modelling of the surface and in sedimentation.

Although the periglacial processes recurring in a number of subsequent phases did not completely change the character of the landscape shaped by normal erosion, they still considerably altered it. The erosive valleys, owing to derasion, became wide and flat, and dell formation took the place of linear valley cutting. Hill regions with loose soil were transformed into derasional rolling landscapes (Pécsi 1961e).



FIG. 25. "Desiccation (cooling) cracks" filled with lime. (Exposed in the brickyard at Kerecsend)

The upper parts of the calcareous "frost veinlets" 2 to 5 cm thick, penetrating the loam (1) redeposited by solifluction to a depth of 2 to 3 m have suffered a posterior dislocation in the direction of the slope (2). The surface is covered with a black, dark-grey loamy soil. This fossil brown forest soil has assumed a chernozem dynamism (3). The "frost veinlets" start from its lower horizon. Where the slope is steeper, the upper parts of the "frost veinlets" are bent squarely, sometimes to a nearly horizontal position



FIG. 26. Pannonian clay redeposited by laminar solifluction, with fossil loamy soil at the base of the slope (Rakaca Valley)

The undulating layers of the clay and of the loamy soil several cm thick have been folded probably by posterior cryoturbation, frost swelling

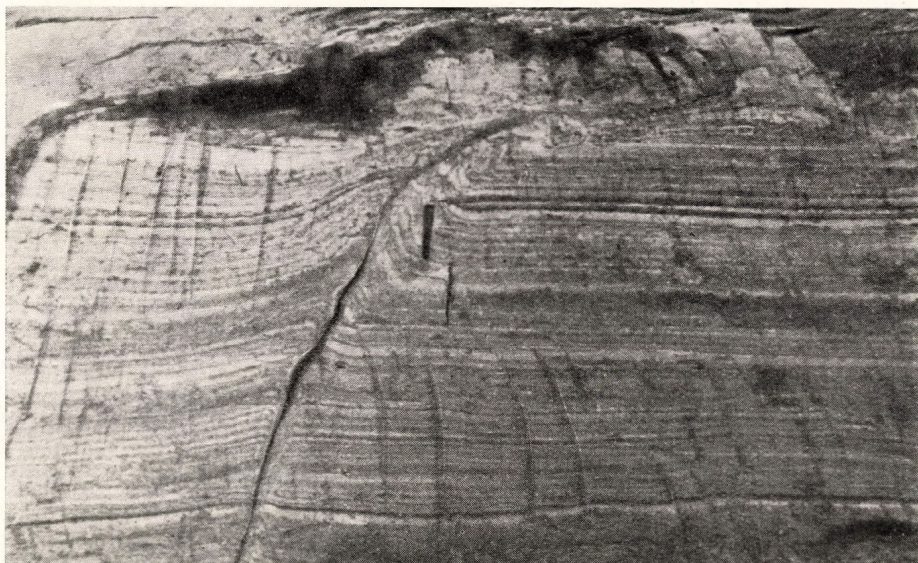


FIG. 27. Sediments accumulated by pluvionivation on gentle slope with angles of 1.5 to 3° (Somogy Hill Region)

The thin-sheets of sand, silt and clay dip slightly towards the floor of the valley, without any wedge. They are partly cryoturbated. The superposed sheets several mm or cm thick, mainly consisting of fine sand fraction, have a *Bänderton*-like structure



FIG. 28. Stratified, coarse-grained periglacial slope debris with coarse slightly rounded granite pebbles and chiefly granite gravels; the stratification corresponding to the slope forms bed planes without wedges, in which fine and coarse grained packets alternate (Velence Mountains)



FIGS 29—30. A minor U-shaped dell formed in the slope loesses overlying terrace II/b of the Zagya River. It is filled with layers of thin, arched black soil and of calcareous products of weathering, mediated by a laminar solifluction or pluvionivation. They have assumed a fossil chernozem character

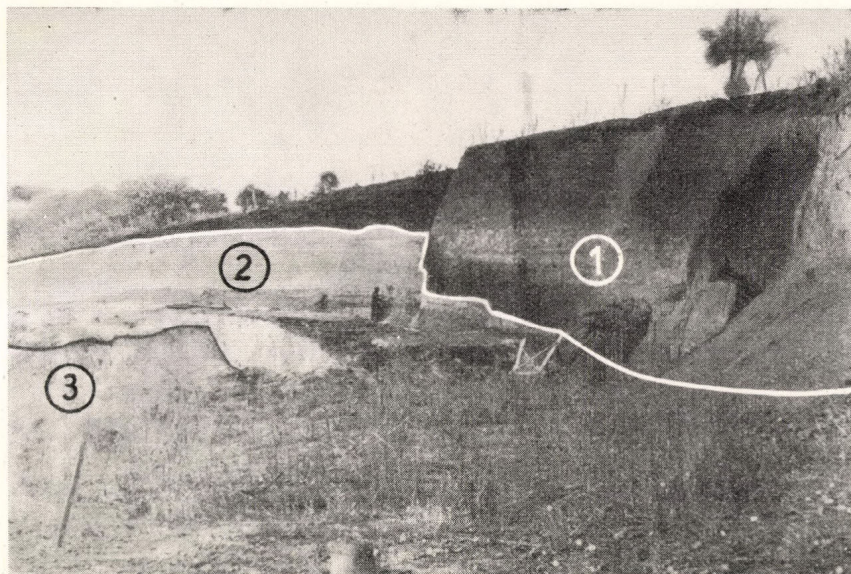


FIG. 31. Dell filled with a dark brown fossil soil. Degrading surface inversion, the ancient dell being now a hilltop (Eger, brickyard in Noszvaji Street)

1 — Dell-filling material mainly redeposited, stratified clayey forest soil, 2 — thin-bedded solifluction loam and clay, 3 — Oligocene clay

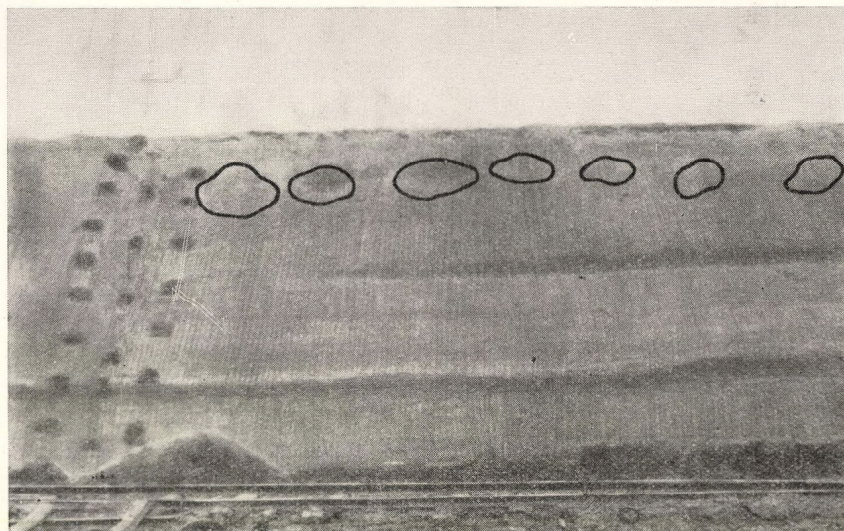


FIG. 32. Dell formed in several phases and filled up by various kinds of slope processes. (From the quarry of the brickyard at Szombathely)

The dell formed in Upper Pannonian brown loams and affected by solifluction is lying mainly on sands and thin clays. At the sole of the dell there is a thin, crescent-shaped bed 0.3 m thick of clayey gravel and gravel, overlain by stratified greyish-brown solifluction loams on which a pseudogley soil has been formed. Then two more sequences of gravels, loams, fossil soil are finally covered by a fossil soil containing very nice clay polygons

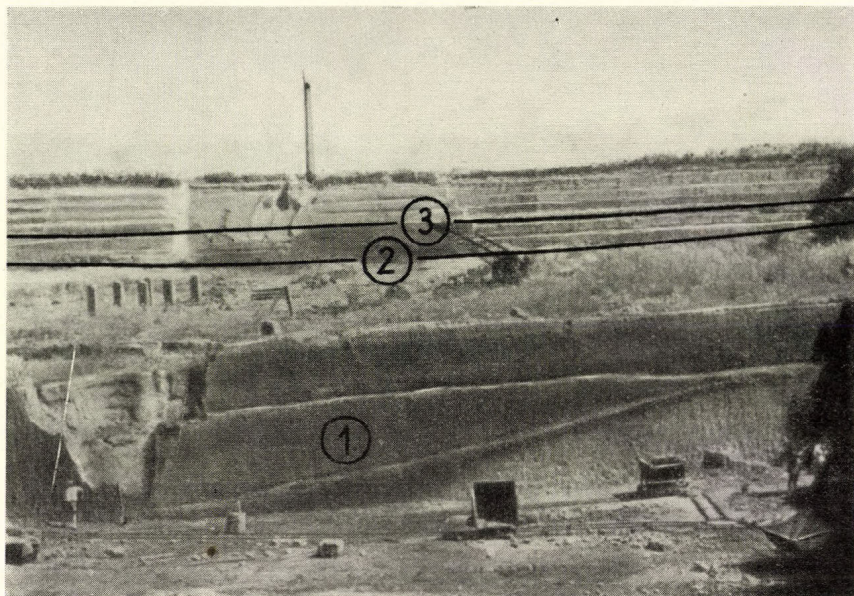


FIG. 33. Würmian dell covered with thick slope loesses and filled with chernozem soil (1) redeposited by pluvionivation and solifluction. In the slope, loess cover, two additional fossil chernozem soils have developed (2, 3). In the sands underlying the dell specimens of *Coelodonta antiquitatis* were found (marked x)

b) Dells¹

We could distinguish the following two types of derasional surface denudation and sediment accumulation: 1. the deepening of dells and their accretion; 2. over-all uniplanar denudation of slopes and accretion at the base of the slopes and at the bottom of the valleys. The processes taking place in dells represent a transition between the linear valley forming processes and the periglacial pluvionivation-solifluction processes denuding the slope in one plane.

The detailed analysis and the typology of dells having been extended to the whole of Hungary (Pécsi 1955a, 1961e, Ádám, Marosi and Szilárd 1959, Székely 1961, Peja 1958) have shown that derasional, just like erosional, valleys are not associated with single rock types. Thus dells are not rock-morphological but rather climatic-morphological phenomena. Dells can be found on granite, dolomite, Tertiary limestone, clay, igneous rocks, slope loesses of various types as well as on typical loess, loam, sand and even on gravel sheets and terraces (Pécsi 1961e). They occur most frequently on slopes, but can also be

¹ Longer or shorter, wide valleys with dish-like cross-section as well as long and narrow half-cylindrical dry valleys where no traces of linear erosion are visible are called typical dells (derasional valleys) (Figs 34–38).

found on residual terraces and near relatively deeper valleys on plains lying somewhat higher.

In a considerable part of the Hungarian hill countries (in counties of Tolna, Baranya, Somogy, Vas, Zala, in the area of the Bársonyos and the Northern Basin range, in the Mezőföld and on the gravel sheet of the Trans-Rába

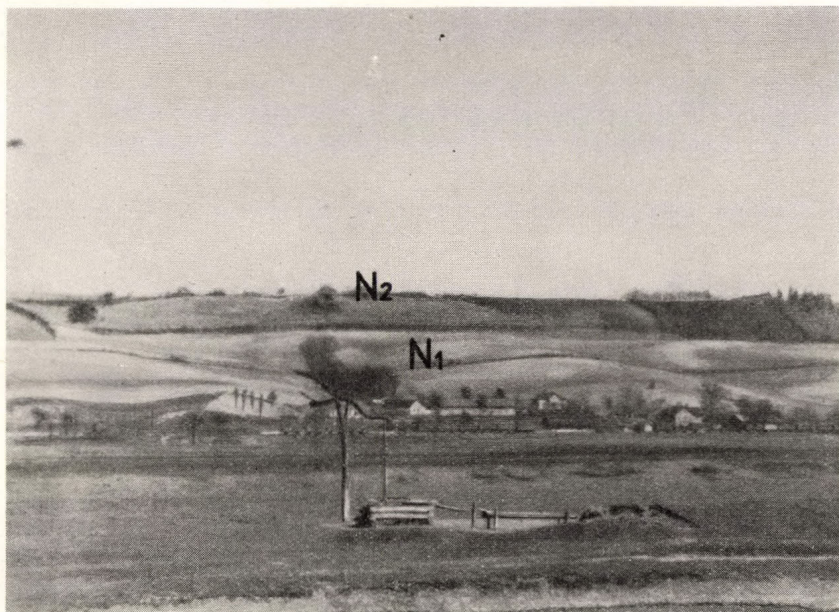


Fig. 34. Slope modelled by dells. (Western border of the Tolna Ridge, with the valley of the Kapos River in the foreground)

The stepped western slopes of the Tolna Ridge made up of Upper Pannonian clays, sands and upper Pliocene sands are covered with slope loess, loessy sand and with loose solifluctional and slump sediments. The levels marked N_1 and N_2 present the first and the second derasion horizons above the Kapos Valley. They are dissected by flat dells 100 to 300 m broad, so that the horizons dip almost everywhere towards either the main valley or the dell. The spurs are still subjected to a conspicuous soil erosion, while the accumulation in the dells is insignificant. The exposures in the cross-section of the spurs (brickyards at Tolnanémedi and Keszőhidegkút, etc.) show that the dells have moved from place to place, the former valleys being now completely filled up, the fact to denote the ridges — spurs — were accumulated by derasion

Region), dells together with the erosional-derasional valleys and the adjacent sloping surfaces make up more than a half of the relief. In smaller areas they include the major part of the surface. In such places the number of the dells is a multiple of that of the erosional valleys.

Most dells were not formed primarily by linear erosion. There are certain types of erosional-derasional valleys, generally the larger and longer ones which were formed by derasive and erosive forces in rotation (Ádám, Marosi, Szilárd, 1959). Certain smaller valley types are now being incised by erosion (Ádám 1960, Pécsi 1955a, 1961e, Szilárd 1962).



FIG. 35. Slightly asymmetric, broad, trough-like, longitudinal dell the slope of which has been cultivated in terraces (Tolna Hill Region)

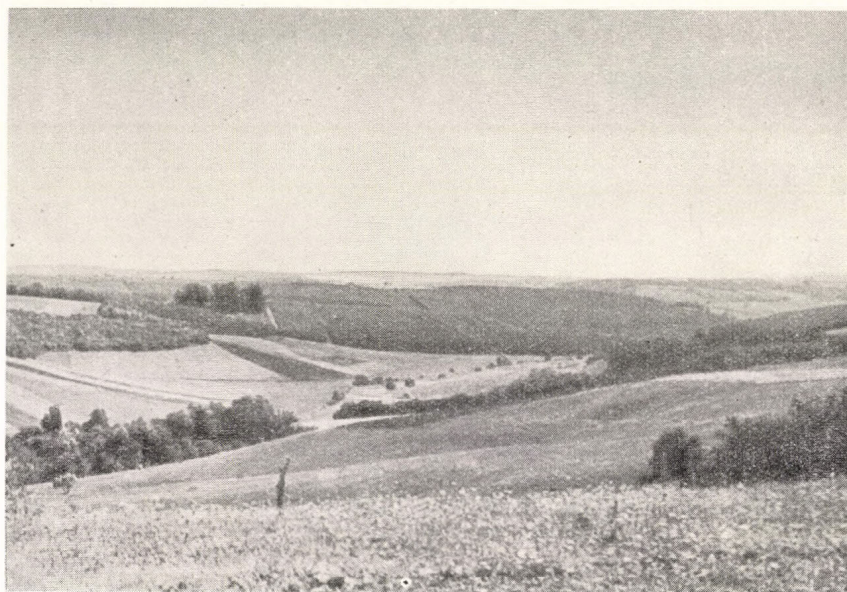


FIG. 36. Broad dell in the Transdanubian Hill Region (Zselic)



FIG. 37. Embryonic derasion niche hanging on the lateral slope of a major dell



FIG. 38. Series of "derasion boxes" formed on one of the lateral slopes of a major dell's head

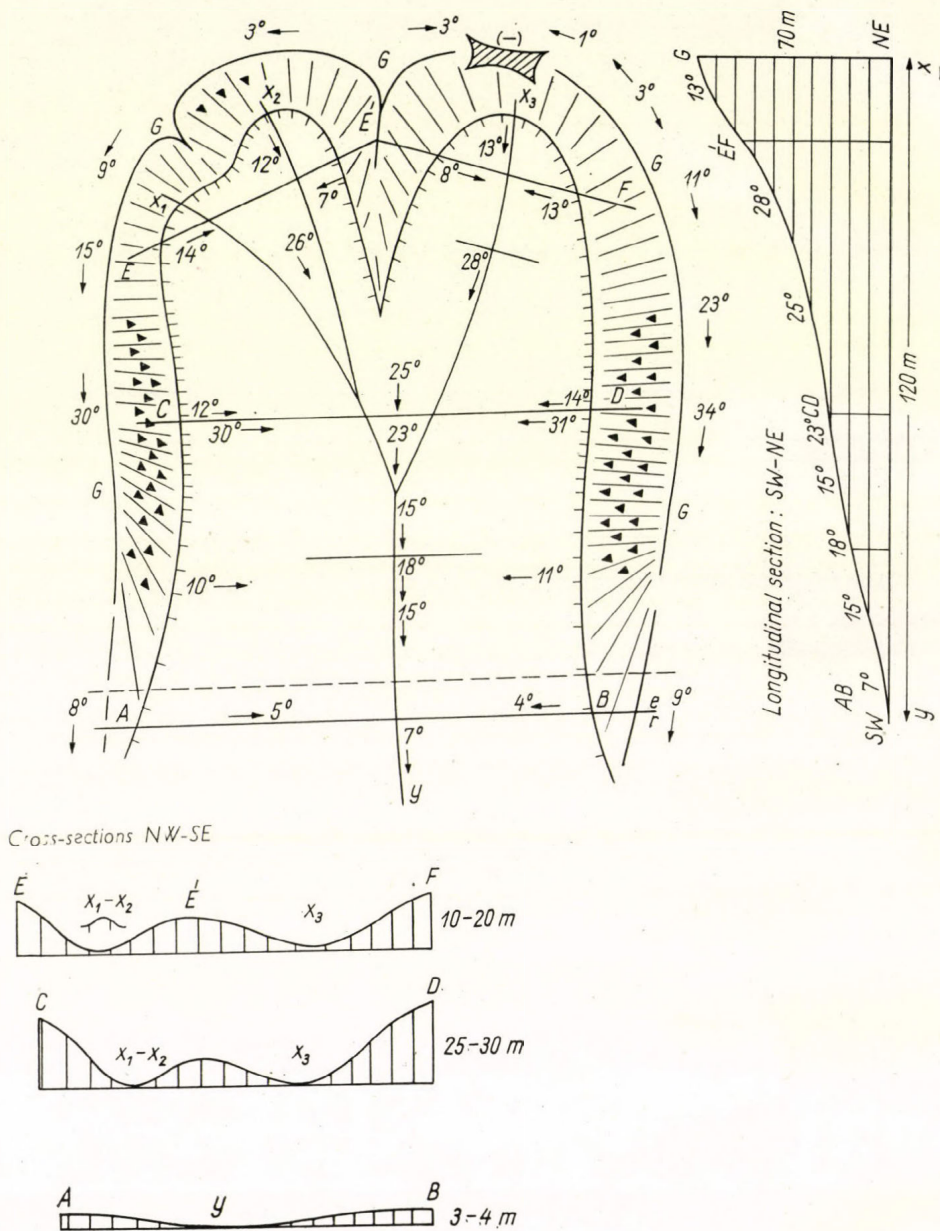


FIG. 39. Slope features of a hanging, derasion twin valley on limestone dolomites, on the slope of the Tata-Bieske fault trough, near Szár

The sizes of the dells chiefly depend on the orographic conditions of the relief, especially, within certain limits, on the relief energy of a relative altitude over 1 km². The gradient curve of the dell which depends partly upon the relative altitude, and partly upon the change in the quality of rocks is the most important feature for us. A common characteristic of the gradient curves is that at the upper wide drainage area of the dell they have a slight angle of dip,

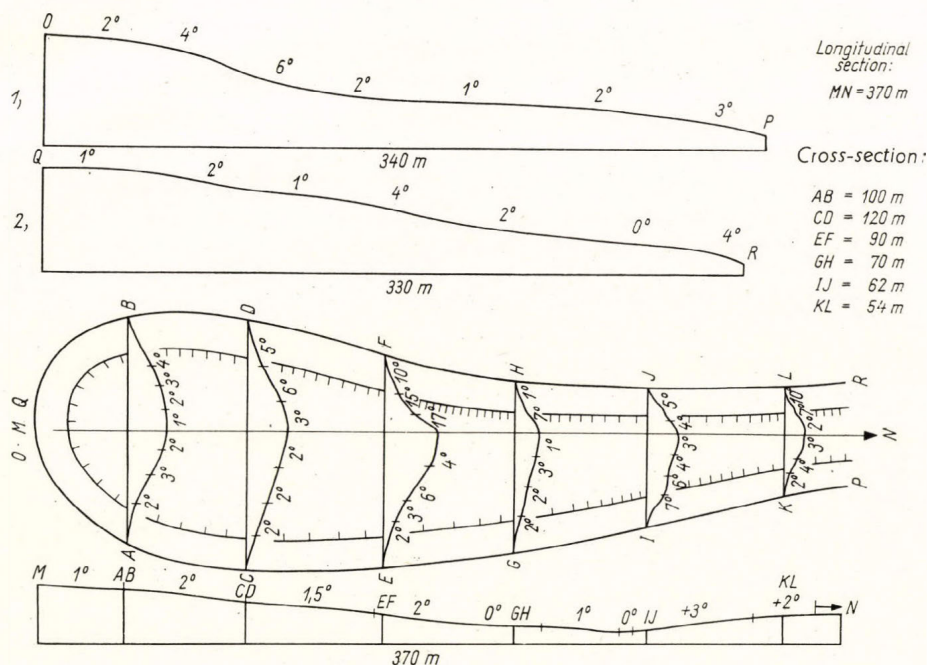


FIG. 40. Longitudinal dell in loamy loess in the region of Aszód. Asymmetric slopes; an alluvial fan has been formed in the lower issue of the valley

but are convex, then at the valley head they become steep, after that at the dell foot they pass into shorter or longer, slightly concave slopes; these patterns of the gradient may repeat themselves over the subsequent sections of the dell (Figs 39—41). The slope patterns of considerable part of the dells subjected to agriculture change even at the present time. However, the majority of the valleys were formed during the last glaciation. This is proved by the fact that the slopes of the dells are covered with stratified sediments often bearing the traces of the periglacial freezing effect. The convex slopes of our dells have recently been largely denuded by tillage, whereas the scourways caused by heavy rains are being regularly removed by ploughing and levelling the soil.

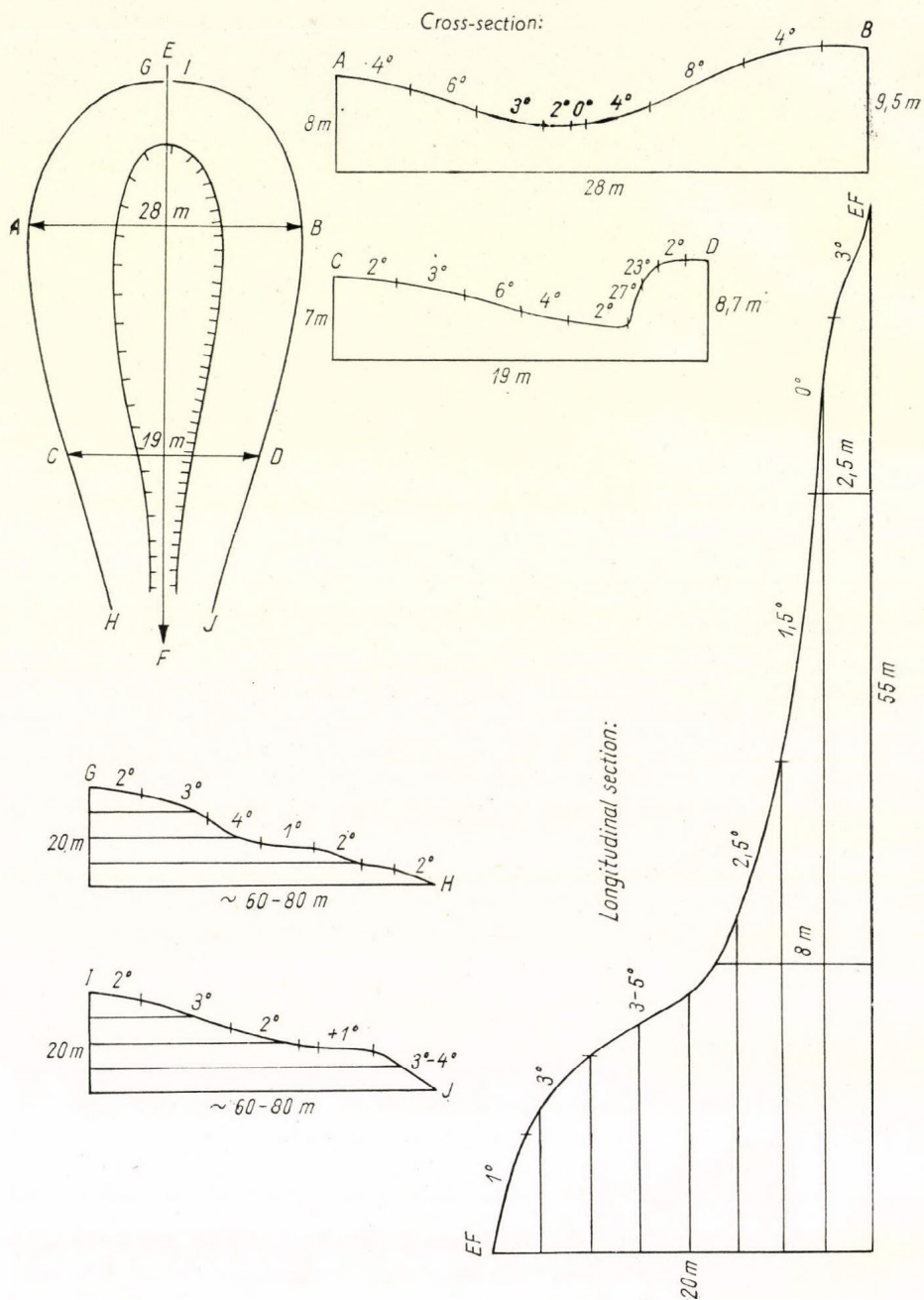


FIG. 41. Hanging dell in the environment of the Hévízgyörk railway station. Except for the valley section C—D, the slopes are symmetrical

c) Principal Types of Cryoturbation

During the thirties research workers dealing with Quaternary deposits observed some cryoturbational and solifluctional formations in Hungary (Szádeczky-Kardoss 1936, Bulla 1939a, Kerekes 1941). These investigations had to be taken up again after a pause of nearly two decades, when Pécsi, while studying the terraces of the Danube Valley, succeeded in typifying the

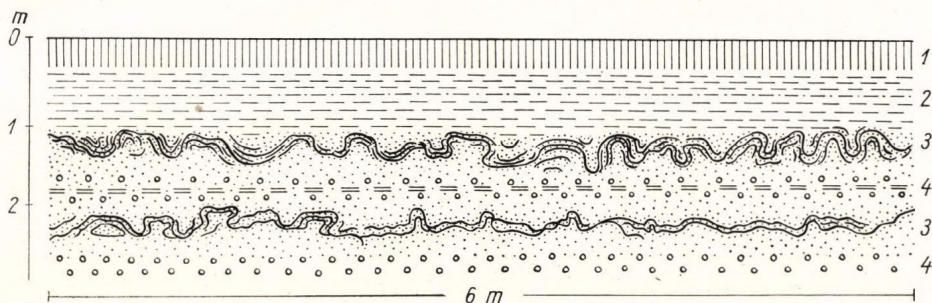


FIG. 42. Slight cryoturbation covered with flood plain silts on the recent alluvial fan of the Little Plain

1 — Humic, sandy flood plain silt, 2 — calcareous sandy flood plain silt, fine-grained sand 3—20 to 30 cm thick cryoturbated and intercalated by silt bands, 4 — sandy gravel undisturbed by frost (gravel pit, Barátföld farm, Bécsi street)

This cryoturbated form has been found by the author to be a remnant of the slightest possible frost effect in Hungary. It has a striking resemblance in character and size to the cryoturbation forms in the foreland of the *Saalepausälkes* in South Finland, formed presumably at the beginning of the *Saalepausälke* stage

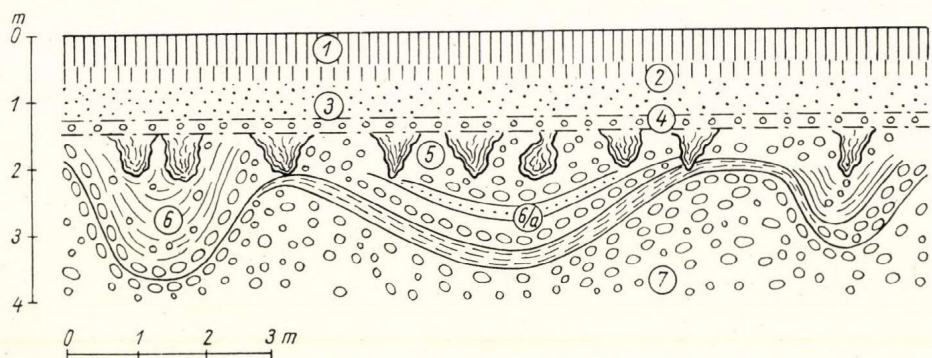


FIG. 43. Cryoturbation type of terrace II/b in the gravel quarry of Vác

1 — Chernozem, 2 — remnants of a former brown forest soil, 3 — calcareous running sand, 4 — stone pavement, 5 — small frost sacks and frost wedges filled with sand, sandy silt, 2nd generation of cryoturbation, 6 — gravel polygon, 1.5 to 2 m long, the inner core consisting of sandy silt and sandy calcareous silt with scattered gravel grains, 6/a — gently arched sand and gravel layers affected by frost, 7 — gravels of terrace II/b of the Danube

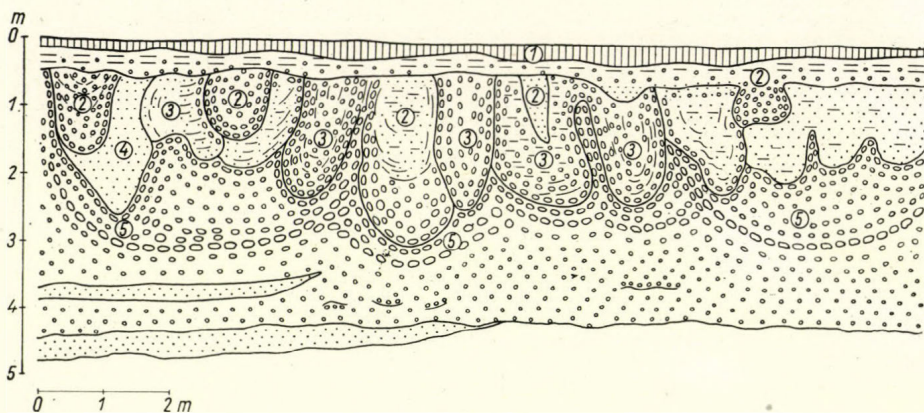


Fig. 44. Stone polygons produced by frost pressure (gravel quarry, Budapest—Pestlőrinc)

1 — Sandy chernozem soil, 2 — gravelly sand core mixed with red-brown forest soil coated with a gravel mantle, 3 — highly calcareous sand, sandy lime dust containing sporadic, irregular gravel pockets, 4 — calcareous lime containing scattered gravel grains, 5 — pebbles arcuately bedded in sandy calcareous silt and, outwards, in yellowish-brown sandy clay and loam. Stones (10 to 15 cm Φ) form separate bands. It is characteristic of this arrangement exhibiting an onion structure that the gravels, which are finely grained in the centre of the core (3, 4), become gradually coarser outwards. The polygons in the section represent, in fact, the inner parts of some major stone polygon

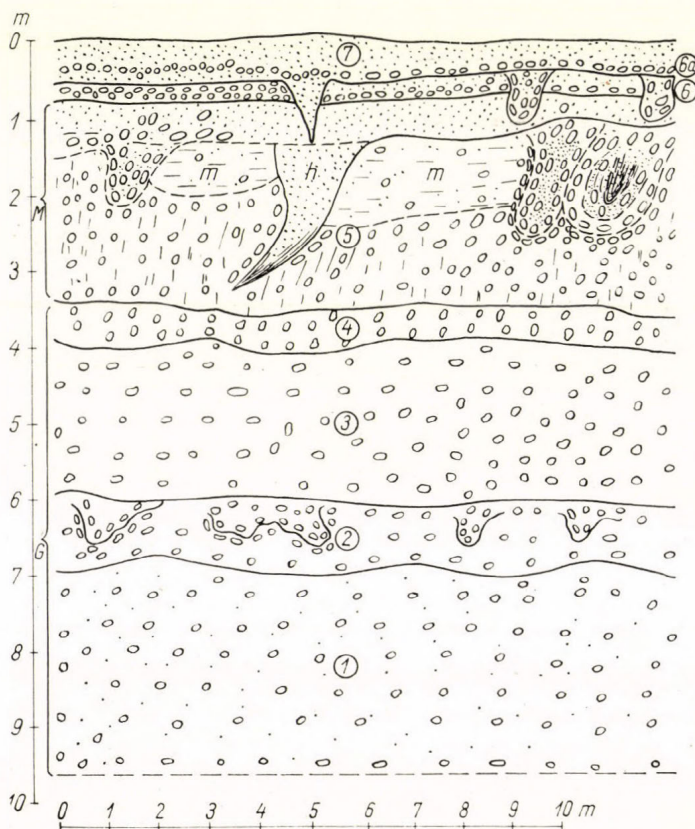


Fig. 45. Types of subsequent periglacial soil-frost phases in the oldest alluvial fan terrace south of Budapest

1 — Horizontally bedded greyish-yellow sandy gravel, 2 — red-brown gravel slightly affected by cryoturbation, 3 — yellow sandy gravel bedded horizontally, 4 — red-brown gravel with surface discordancies, 5 — gravels bedded in red-brown loam, with ice wedges and gravel sacs, 6 — smaller gravel sacs (stone polygons) and ice wedges bedded in sand; 6a — gravel pavement produced by solifluction; 7 — recent blown sands; G — Günz gravel, M — Mindel gravel, m — fine lime dust, h — calcareous sand filling the ice wedges

cryoturbational phenomena in a way (1959a, 1961b, c) which even allowed certain relative age determinations. In recent years the members of the Section have collected a larger number of new data in the areas of their research activity (Pécsi, Ádám, Marosi, Szilárd, Góczán, Somogyi). On the basis of the results of our former investigations and of the observations made during our study tours both in Hungary and abroad, we have described a number of cryoturbational phenomena which have not yet been characterized.

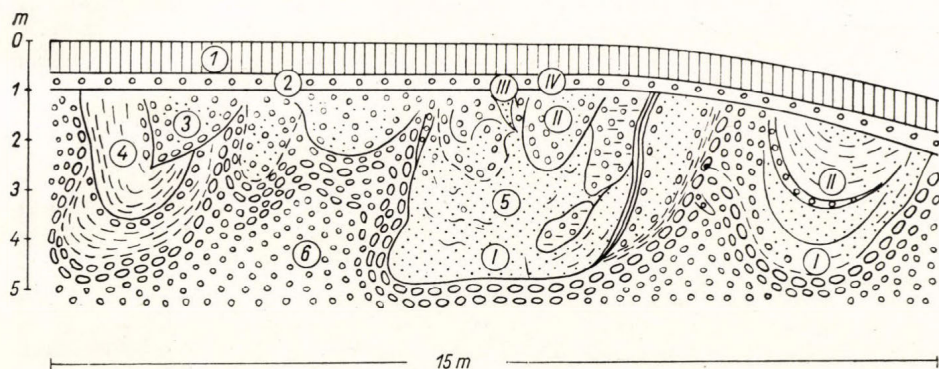


Fig. 46. Soil frost phenomena developed in several phases (gravel pit at Győr—Sashegypusztá). The exposure lies in the gravels of an older alluvial fan of the Danube in the Little Plain. The following processes can be distinguished:

— old, large stone polygons, II — smaller polygons penetrating the large ones, III — group of ice wedges, IV — gravel layer affected by solifluction; 1 — chernozem soil, 2 — gravel pavement produced by solifluction, 3 — gravels filling the ice wedge, 4 — calcareous sand and silt filling ice sacs (stone polygons), 5 — sand material filling the sacs, 6 — terrace gravels disturbed by frost phenomena. The stone polygons of generations I and II are coated by red soil rags

Studying the surface of terraces and alluvial fans cryoturbational forms dating from four subsequent phases could be differentiated: a) late Würm phenomena, b) early Würm and middle Würm glaciation patterned grounds, c) frozen soils from the Riss glaciation, d) cryoturbational phenomena from the (lower) early Pleistocene. Most complex form assemblages are represented by those dating from the early Würm, the middle Würm glaciation, and the Riss glaciation (Pécsi 1961b, 1961e).

The latest forms are minute sacs, frost wedges and fine foldings, half a metre long at the most (Fig. 42). In the second flood-free terraces, situated above the flood plain, the frost wedges, the irregular gravel sacs, and the layers deformed by frost penetrate two or three times deeper than those mentioned above. Here, besides larger forms a younger generation is also to be found (Pécsi 1961b, Fig. 43).

The cryoturbational phenomena, apparent on the surfaces of higher or older alluvial fans and gravel sheets, are more extensive and more complex; they may have been formed in several phases, the syngenetic cryoturbational forms being frequent (Figs 44—46). Structure ground types occurring most frequently are the 2—4 m long frost wedges (Figs 47—49), frost sacs, stone rings (Fig. 50),

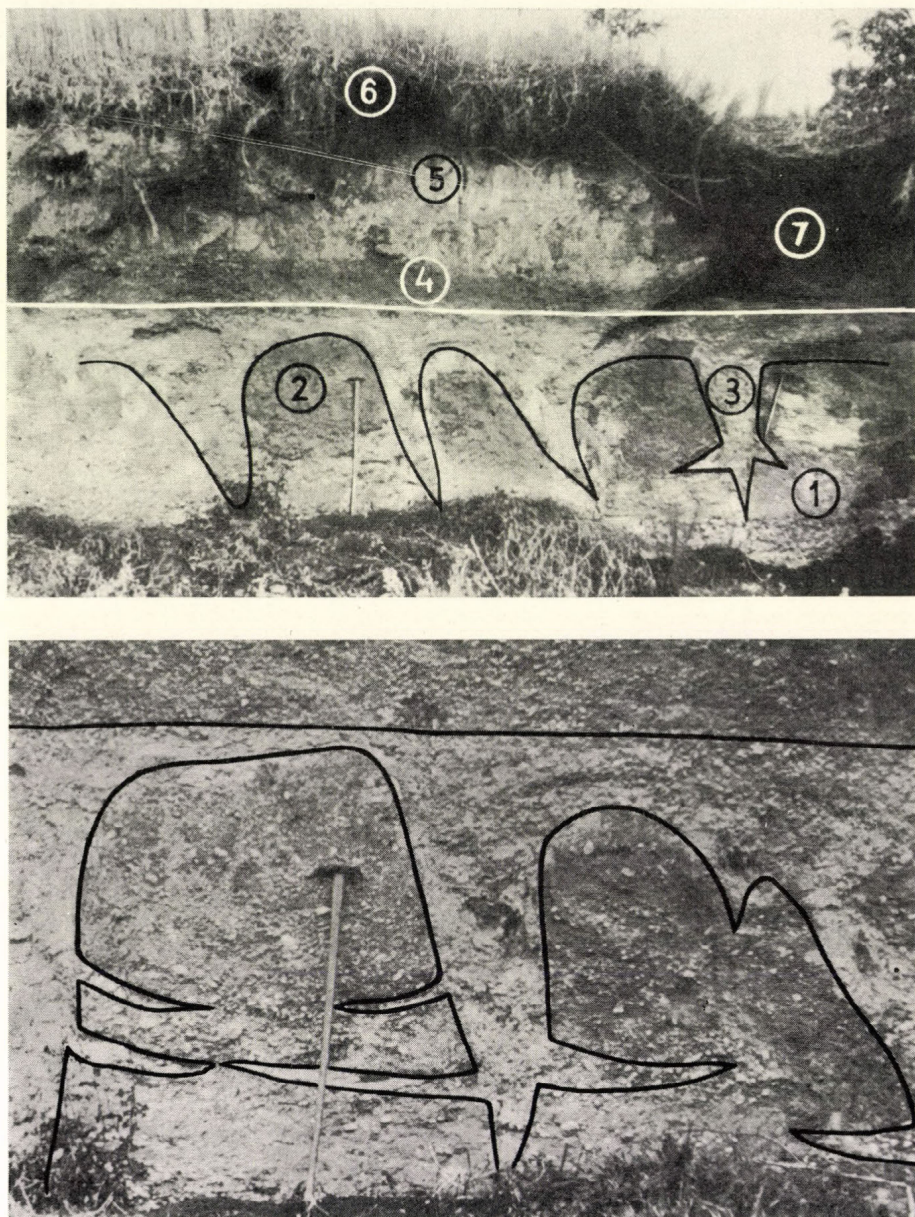


FIG. 47—48. Ice wedges of medium size filled with loamy gravels on the gravel sheet in the Trans-Rába Region (Vép, gravel quarry)

The gravel sheet was probably deposited as an alluvial fan during Riss glaciation (or during the Riss—Würm substage). First, red clays (1) formed on it, then the formation of stone polygons (2) and a subsequent formation of ice wedges (3) were covered by clayey solifluctional gravels (4) intruding also the ice wedges. Next the solifluctional loam was deposited (5) on which the soil (6) started to form. Pits excavated in this surface were used for dwelling (7) in prehistoric times



FIG. 49. Deformed ice wedges in the Trans-Rába Region gravel sheet

The gravel redeposited by solifluction on gentle slope was mixed with sand, clay lumps and clayey brown forest soil. During redeposition the gravel was coated with brown clay film and clay crust (1). The ice wedges (2) were formed after this process, and by repeated regelations were deformed and dilated in a sac form. The ice wedges have a filling material of sandy gravels coated by clay. The surface consists of a clayey, brown forest loamy soil (3)

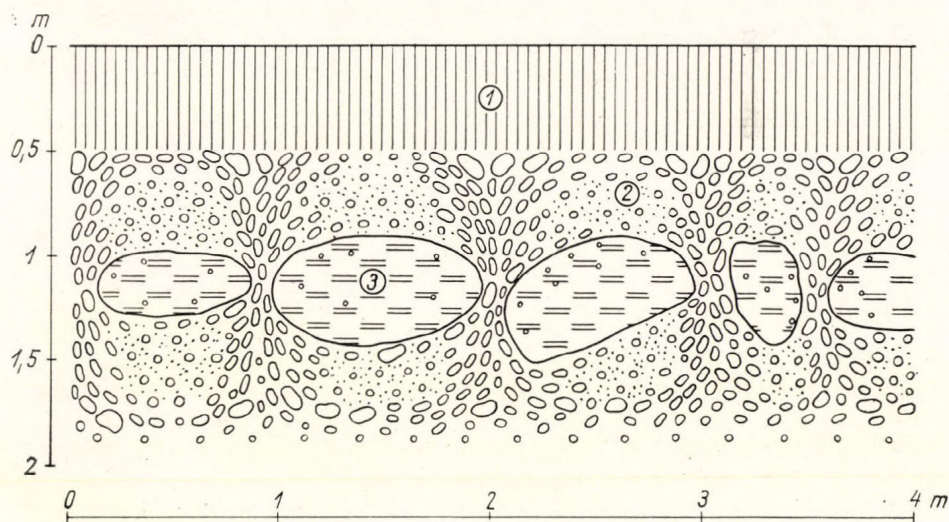


FIG. 50. Stone polygons — stone rings at Mosonszentjános, on an alluvial fan of the Little Plain

1 — Grassland clay, fen clay, 2 — coarse gravels markedly arenated around the masses of clay, 3 — yellowish, greyish-yellow sandy clay

kettle-shaped gravel polygons (Fig. 51), remnants of hydrolaccoliths (Figs 52, 53), gravel (stone) polygons measuring 4–5 m in diameter (Fig. 54), frost veinlets and undulately deformed beds (Figs 55, 57).

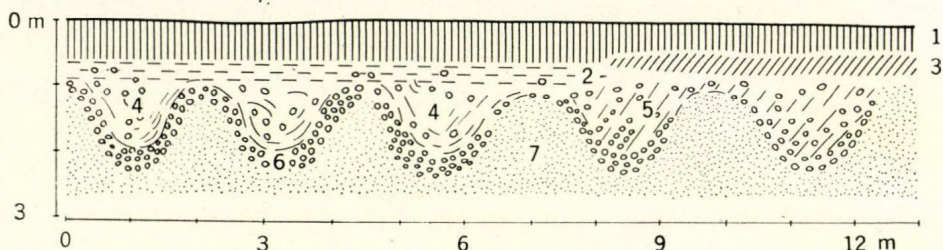


Fig. 51. Type of cryoturbated gravel kettles of the more recent alluvial fan in the Little Plain. A variant of the form remnants of the stony tundra (Mosonszentjános)

1 — Grassland chernozem, 2 — silty gravel with accumulation of lime, 3 — horizon "B" of the red-brown forest soil, 4 — calcareous silt with sporadic gravel grains filling material of the stone polygon, 5 — gravel material, mixed with red-sandy loam, of the polygons underlying the horizon "B" of the brown forest soil, 6 — arcuate gravel mantle of the polygons, 7 — grey grit-like sand

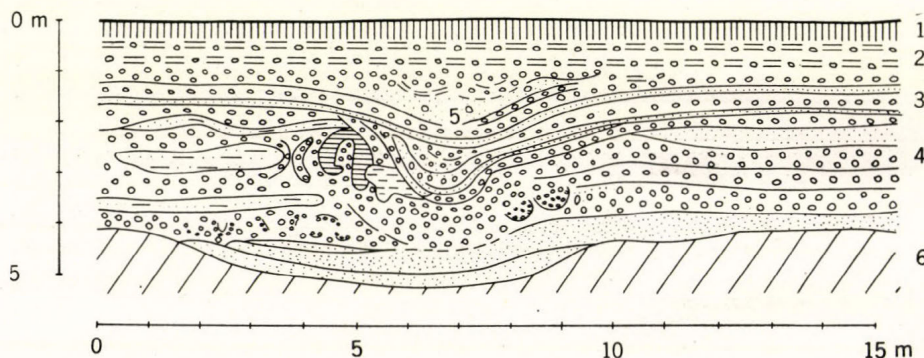


Fig. 52. Cryoturbation type of alluvial gravels densely interrupted by sand veinlets (a hydrolaccolith form remnant?). (Hegyeshalom, gravel quarry)

1 — Grassland chernozem soil, 2 — material of yellow, sandy clays and loessy silts mixed with gravels by solifluction, 3 — alternating sand and gravel beds, 4 — bed of sandy gravels with subordinate sand lenses penetrated by the kettle polygon, 5 — kettle-like frost form (thermokarst) in which the layers 5 to 20 cm thick of sand gravel, sandy and clayey gravel are arranged in an arched superposition. The mantle of the cryoform consists of silt and lumps of sandy clay. The second bed affected repeatedly by slight solifluctions and cryoturbations was deposited later.

The patterned ground of sand surfaces are less varied. These are generally sandy-loamy sac soils of diverse types (Fig. 58) (Marosi and Szilárd 1957, Marosi 1960, 1962a, Szilárd 1962, Pécsi 1961b). The cryoturbational phenomena of the flat and gently sloping clay, sandy clay and loam surfaces are characterized by soils furrowed in stripes (Fig. 24), frost cracks, frost wedges and clay polygons; locally, solifluction causes them to be carried down the slope and to be deformed (Pécsi 1961b, Figs 2–5).

The limestone and dolomite surfaces of Hungary have also exhibited frost wedges and enormous stony polygons. In addition, on granites, dolomites

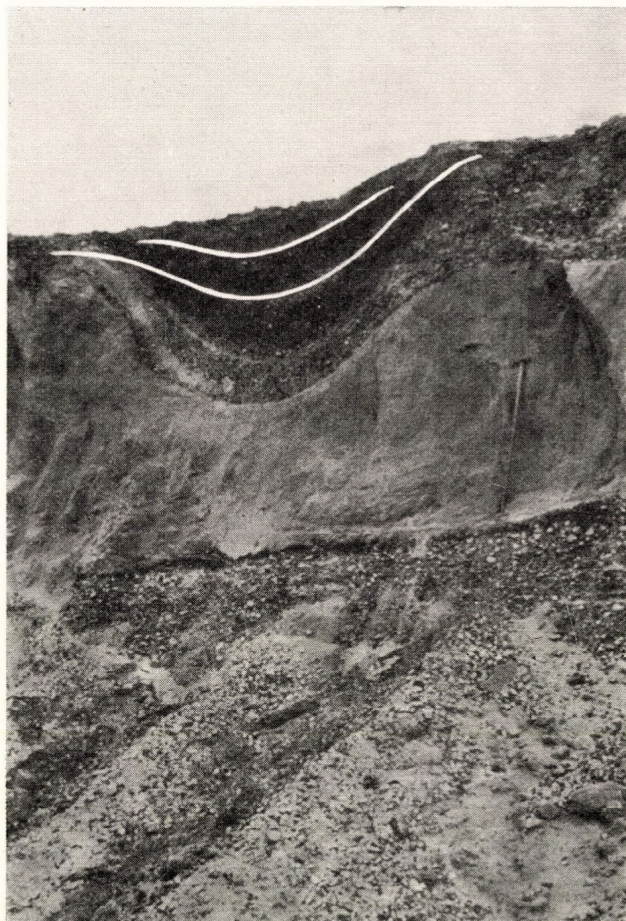
and igneous rocks there often occur cliffs, towers and buttes of bizarre shape produced by frost.

On the basis of the types and the distribution of soil frost phenomena (Fig. 56) affected by cryoturbation it can be stated that during the glaciations permanently frozen soils had periodically been formed over large isolated areas in Hungary, too. In certain periods of the last glaciation the thawing "season" soil might have been generally 2 to 3 m, occasionally even 4 to 5 m thick. In order to account for the development of such processes, we must presume that the mean annual temperature of the coldest periods is likely to have been $-2, -3^{\circ}\text{C}$.

The chronological division of the forms of cryoturbation has been accomplished on the basis of their types and form assemblages as well as of their comparison with the fossil soils. Form types of different ages enable us to determine the relative ages of certain surface portions or terraces, too.

FIG. 53. Type of flat gravel kettles (gravel quarry at Hegyeshalom)

Rather young Pleistocene alluvial fan (Riss glaciation) at the Danube in the Little Plain, where a molar of *Elephas antiquus* was found. In the flat gravel kettle, numerous sand and gravel layers show onion structure different from that of a normal stone polygon, the inner fine-grained core of which is surrounded by gravels the coarser the farther from the centre. Tshi type cannot be explained by any of the stone polygon theories. The layers proceed from within the gravel kettle undisturbed. This remnant might be ascribed to the ice sheets — hydrolaccoliths, ice laccoliths — that were formed at numerous spots in the substrate, and brought about flat elevations, tundra mounds, like those observable now in the southern marginal zone of the permafrost Siberian Lowland. By degradation, the frozen mounds gave place to the negative forms, kettle-like deepenings, where thawings accumulated melt waters the ice lenses of which, when frozen and swollen, deform the loose strata. Since the permafrost checked frost pressure from acting downwards, the strata may have been compacted to a certain extent. By repeated thawings of the ice lenses, the strata compacted would decrease in volume, hence the flat kettle form



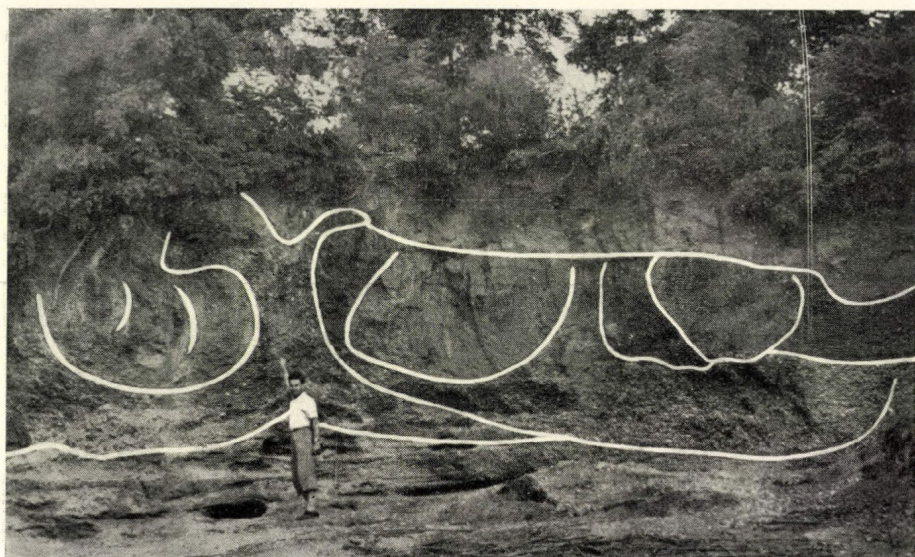


FIG. 54. Barrel-shaped major stone polygons formed under frost pressure (Kemeneshát gravel sheet, Ostffyasszonyfa)

Exposed on the gently sloping sole of the dell running towards the present flood plain of the Rába. The core of the kettle-shaped stone polygons of 3 to 4 m in diameter consists of medium-grained sands coated by clay film. The diameter corresponds to $7/5$ of the depth



FIG. 55. Pannonian clay layer deformed by frost, on gentle slope (Galgahévíz)

Each clayey layer shows 8 to 10 m long regular waves reaching 1.5 to 3 m below the surface. Here the folding is due to cryotectonic disturbances. In the deeper horizon of the exposure, the folding of the strata disappears

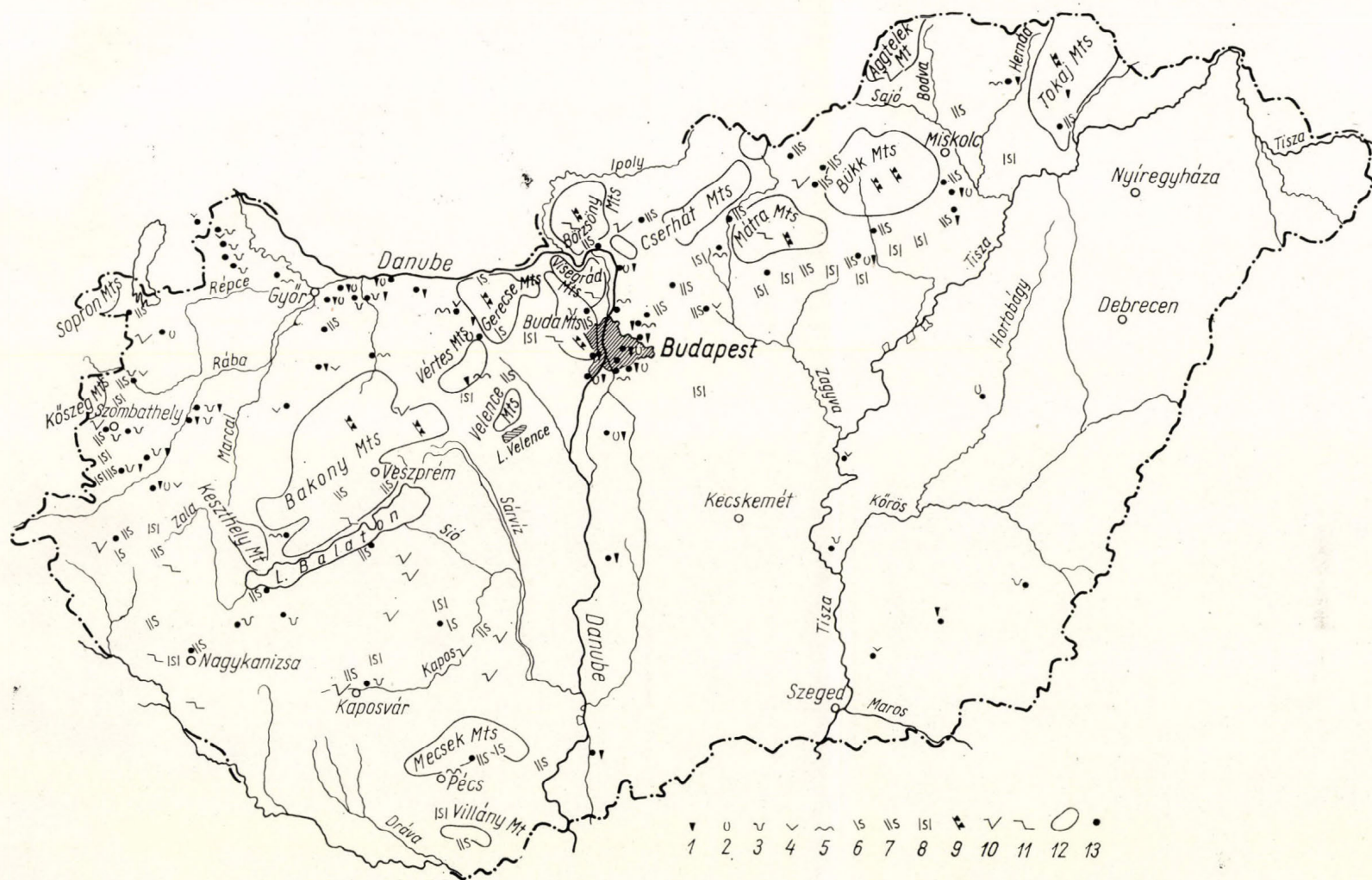


Fig. 56. Principal types of periglacial cryoturbation forms in Hungary

1 — Frost wedge, 2 — sacs (gravel, sand, loam and clay sacs), 3 — kettle-shaped regular polygon (in gravel, sand), 4 — subsoil affected by frost, 5 — cryoturbation in general, 6 — traces of solifluction on slope, 7 — sediments accumulated by solifluction on slope, 8 — solifluction deposit in general, 9 — periglacial block facies, 10 — periglacial valley asymmetries, 11 — cryoplanation terraces, 12 — parts of the Hungarian Central Mountains, 13 — remarkable exposures.



FIG. 57. Cryotectonic deformation of strata (abandoned bauxite quarry at Gánt)

The upper folded stratum is represented by Eocene clayey marls 3 to 5 m thick, underlain by yellowish clays. Under the cryoturbated upper series, however, the Eocene beds exhibit normal bedding.

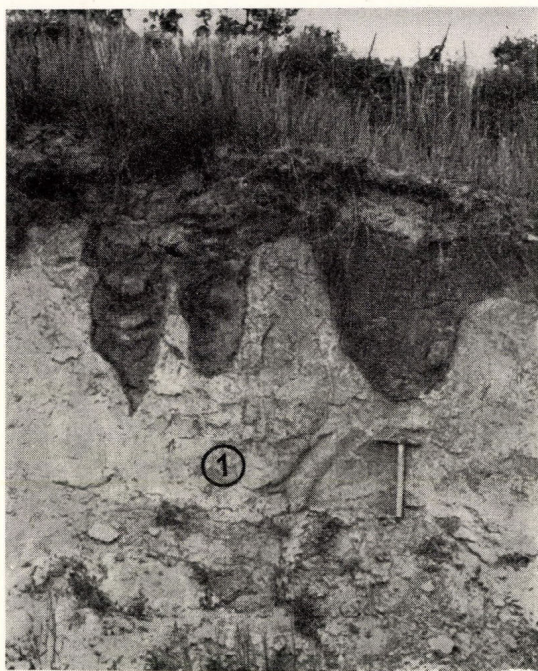


FIG. 58. A type of loamy soil with sand sacs (Pilisvörösvár)

On the side of the gently sloping dell there are remnants of spotty tundra (*Flecken-tundra*). The finely bedded sand intercalated by thin strips of dolomite pebbles (1) dips almost parallel to the inclination of the surface. The cryoturbation forms 80 to 150 cm deep and 50 to 80 cm wide, resembling reversed beehives, are filled with loamy brown forest soil and penetrate into the mother rock

Recognition of the feature types of the periglacial soil frost also furnishes evidence to the degree of actual surface modelling and to that of the denudation of slopes and of the surface soil, as the degradation of the present surface plays naturally a subordinate role on slopes where the markings of the periglacial cryoturbation may be encountered below the soil profile. Otherwise, actual destruction of the surface may be supposed, and this prompts us to define also the scale of this destruction by means of other methods (Pécsi 1961*b*).

DENUDATION IN GENERAL

a) *Climatic Geomorphology*

From among the works dealing with the process and rate of surface modelling by the external forces, we have to mention especially B. Bulla's studies on climatic morphology and his book *General Physiography* (1954a). External forces bring to bear their modelling effect in the different climatic regions depending on the climatic conditions. Bulla (1954a, 1954c) subdivided the surface of the earth into eight climatic-morphological regions. He characterized the association of the different feature types corresponding to the climate of each particular region. In many papers, he studied in detail the feature-shaping function of linear erosion characteristic of the climatic-morphological regions of the temperature zone, pointing among others to the formation of the Central-European landscape abounding in valleys as being normal for the temperate zone. Nevertheless, in Central Europe the now existing surface features have been modelled not only by the fluvial erosion of the temperature climate but — besides the periodically recurring crustal movements of the shifting of climatic zones having been repeated several times since Late Tertiary times — also by external forces of the tropical, subtropical and periglacial realms of climatic morphology as a consequence (Bulla 1954c). These processes figured in the dialectic development of the relief even several times for longer or shorter periods. In addition, Bulla has emphasized that, with respect to their genesis, the fossil — dying out, perishing — form elements are found together with forms produced by processes taking place at present in the temperate zone.

b) *Tropical Peneplanation and Formation of Piedmont Surfaces*

Bulla has evaluated and criticized in detail the theories of Davis and Penck concerning morphological evolution and the formation of peneplains. In the geomorphological literature he was the first to call attention to a third form of peneplanation, the so-called tropical peneplain formation, beside the peneplain formation described by Penck and Davis (Bulla 1956a, 1958b). He suggests that in the tropics, because of the intensive weathering and the large-scale surface wash, the peneplain surfaces have to form, following the laws of nature, on every rising or stable crust portion, and to such heights, up to which the tropic climate, owing to the prevailing high temperature and the heavy rainfalls, is able to denude the surface constantly, continuously and rapidly, that is to control continuous peneplanation. He pointed out that this form of peneplanation can be studied even today in the regions of the tropical savannahs and in the tropic rain-forests along the Equator. Because of its large extension this form of peneplanation is believed to be the most frequent

and the most characteristic one on our globe. The peneplain surface formation of Davis and Penck is considered by Bulla to be less wide-spread and less characteristic. He explains this form of peneplanation in tropical regions by the insignificance of linear erosion and, at the same time, by intensive areal denudation due to the abundant rainfall and to the strong weathering.

In Bulla's opinion (1958*b*) the undulated levels brought about by tropical peneplanation are substantially independent of the tectonic movements of the area, but depend completely on the climate. Therefore, he emphasized that recent tropical peneplain surfaces can not, or only with great circumspection, be used for characterizing the ages and scales of the epeirogenic and diktyogenic movements. He lays stress on this fact just because previously Hungarian and foreign geomorphologists adopting Penck's and Davis' peneplanation theory considered the peneplains of the middle and high mountains to represent senile or primary peneplains dating from the Mesozoic and Tertiary, and ascribed the step-like arrangement of the peneplains to the recurrent uplifts of the mountains in Early and Late Tertiary times, inferring from the individual levels the date and extent of the upheavals.

Bulla refers to the fact that the peneplains of the Hungarian Central Mountains are also due to tropical peneplanation. He does not take a definite stand on whether a single or several tropical peneplain stairways had formed in our Central Mountains, he rather puts forward the hypothesis that the levels of different height had once represented a single tropical peneplain level which was articulated into several steps owing to subsequent tectonic dislocations (Bulla 1956*a*, 1958*b*).

Bulla's theoretical papers on tropical peneplain formation and on the peculiar surface modelling of the individual climatic-morphological regions have exerted considerable influence on the geomorphological investigations in Hungary. Adopting Bulla's theory on the tropical peneplain formation, Pinczés pointed out the presence of a tropical peneplain level in the Neogenic volcanic range of the Zemplén Mountains (1960). In the Mátra Mountains Székely described a tropical peneplain with double steps as well as a subtropical peneplain level, and a Pliocene piedmont benchland (1961). Pécsi compared the positions in space of the peneplain and denudation levels of the Hungarian Mesozoic peneplain block mountains with that of the younger Neogenic volcanic mountains and made comparative observations in connection with the levels occurring on the outer border of the Little Carpathians and on the border of the Graz Basin.

On the basis of the afore-mentioned investigations — without denying the role of tropical peneplanation in the morphogenesis of the Hungarian Central Mountains during the Neogene — Pécsi called attention to the presence of pediments which had undergone truncation in quite recent times, i.e., at the end of the Pliocene and at the beginning of the Pleistocene (Pécsi 1931*a*, 1961*e*). Furthermore, in one of his papers (1961*e*), he illustrated with profiles that the central peneplain surfaces of our Central Mountains are often fairly regularly encircled by three narrow half-planes, the "piedmont benchlands" (Figs 59—61). These series of piedmont benchlands, most of which are conspicuously truncated surfaces, cannot be considered broken portions of a tropical peneplain, the less so as the recent upper Pliocene beds (when climatic

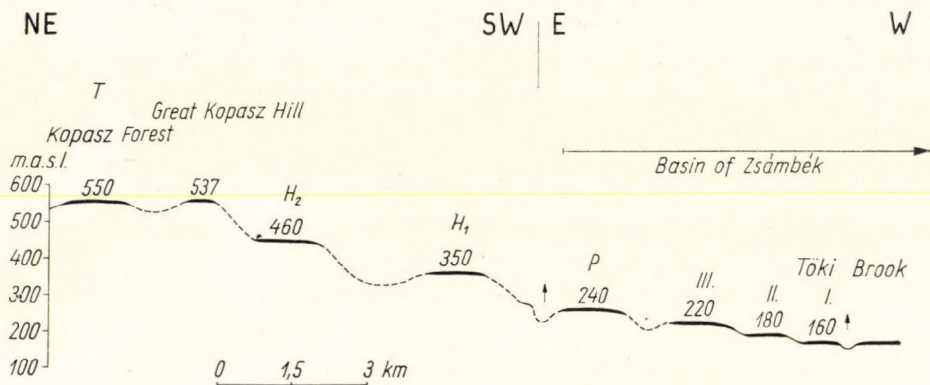


FIG. 59. A sketch of the denudation levels in the western border of the Buda Mountains
T — Tropical peneplain surface, Miocene, *H*₂ — Sarmation piedmont benchlands, *H*₁ — presumably Upper Pannonian piedmont benchlands, *P* — pediment dating from the beginning of Pleistocene; I, II, III — Pleistocene cryoplanation horizons

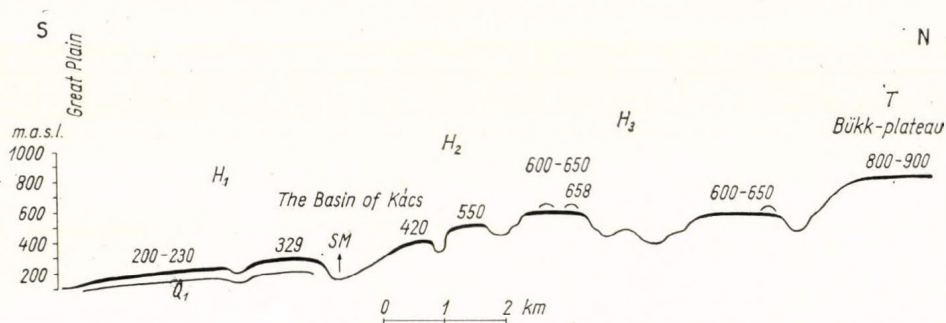


FIG. 60. Sketch of the denudation levels in the southern foreland of the Bükk Mountains
T — Older level of denudation, probably Miocene tropical peneplain surface, *H*₂—*H*₃ — upper Miocene and Pliocene piedmont benchlands, *H*₁ — upper Pliocene pediment which continued to form also during early Pleistocene glaciations (*Q*₁), *SM* — Submountain Basin

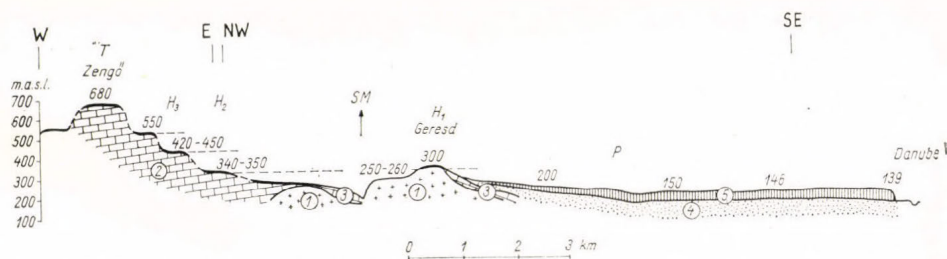


FIG. 61. A sketch of the peneplain level and the piedmont benchlands of the Mecsek Mountains

T — Peneplain surface, *H*₃—*H*₂ — presumed late Tertiary abrasion and denudation benchlands, *H*₁ — upper Pliocene pediment, *P* — early Pleistocene pediment, *SM* — Submountain Basin; 1 — granites, 2 — Jurassicimestones, 3 — Helvetian-Tortonian beds, 4 — Upper Pannonian beds, 5 — slope loesses

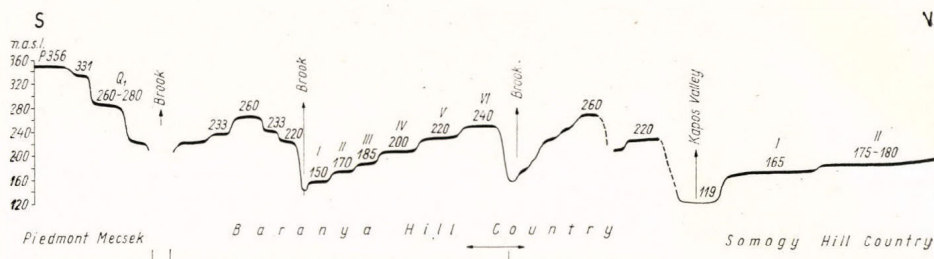


FIG. 62. Cross-section of the northern foreland of the Mecsek Mountains (the Völgység, the Hegyhát) and the southern border of the Somogy Hill Region. The northern slopes are fairly steep while the southern slopes are dissected by several gently sloping stepped derasion horizons

P — Upper Pliocene pediment of the Mecsek, Q_1 — early Pleistocene pediment; I—VI — Pleistocene derasion cryoplanation horizons

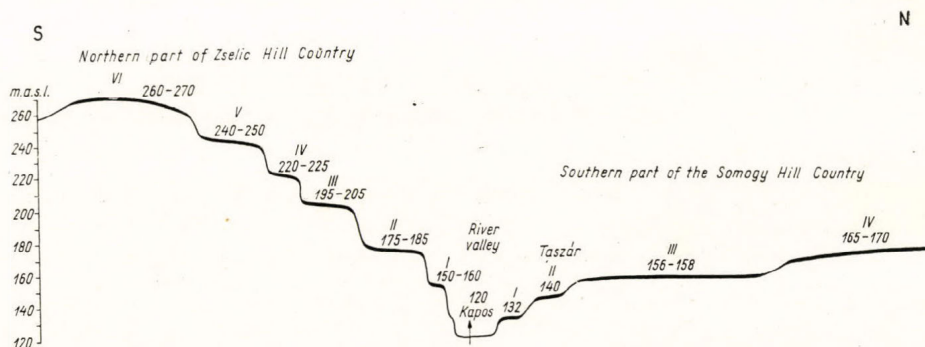


FIG. 63. Derasional-cryoplanational horizons in the Zselic Hill Contry

On the northern border of the Zselic there are narrower derasion horizons with greater slip heights and various relative altitudes ranging from 5 to 7 in number which cannot be derived from any of the evolution phases of the Kapos Valley, nor can it be connected with the level of the ancient valley of the Kapos River. Some of these horizons may have been formed by cryoplanation during one glaciation. I—VI derasion horizons

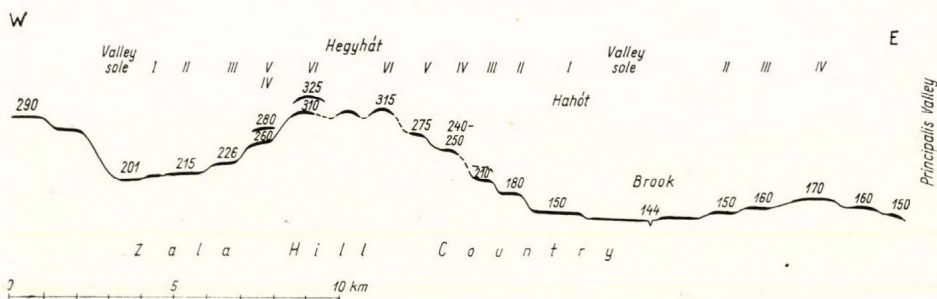


FIG. 64. Cross-section of the meridional erosion-derasion valleys of the Zala Hill Region.

On the western and eastern slopes of the Hahót Ridge, cryoplanation and derasion processes produced derasion — cryoplanation horizons with number and heights different for each particular slope. In some of the lower horizons, the sloping stratified, sandy loess mantle is well exposed. Above certain valley soles the number of the derasion horizons amounts to 6 to 7 including the tops of the hills.

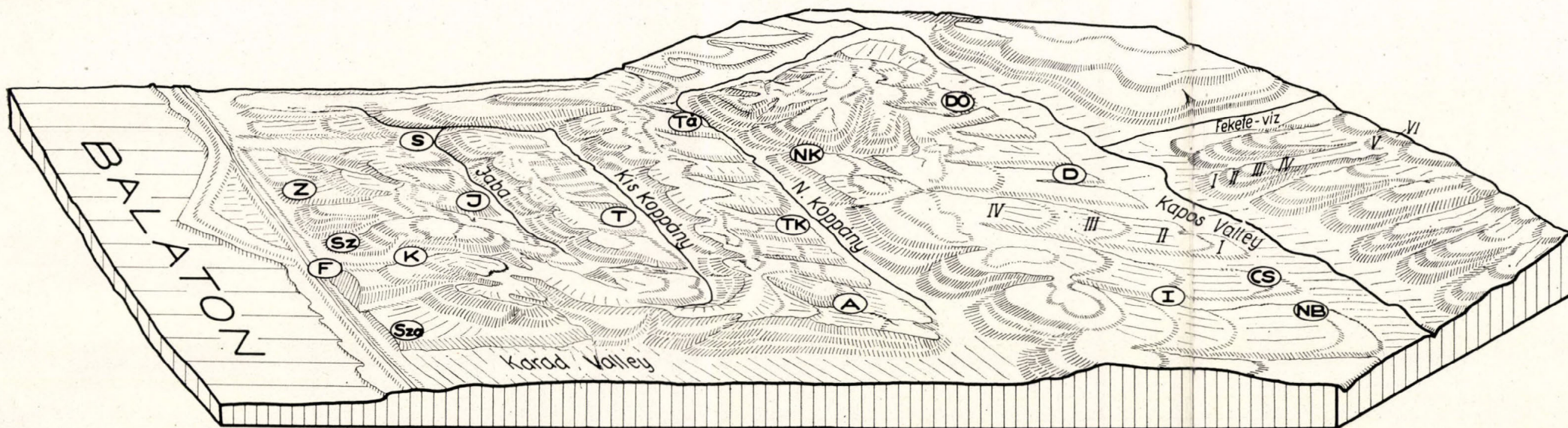


FIG. 65. Derasion cryoplanation horizons in the eastern half of the Hill Region of Outer Somogy, according to Szilárd (1962)

A — Andócs, Cs — Csoma, D — Dombóvár, Dö — Döbrököz, F — Balatonföldvár, I — Igal, J — Jaba-puszta, K — Köröshegy, Nb — Nagyberki, Nk — Nagykónyi, S — Ságvár, Sz — Szántód, Szó — Szárszó, Ta — Tamási, Tk — Törökkoppány, Z — Zamárdi; I—VI derasion-cryoplanation horizons

conditions were different) have also been truncated. This upper Pliocene denudation cannot be explained by tropical peneplanation. The lowermost step is no longer a real "piedmont step" but a pediment (*Flussfläche*) which may even be bipartite. These levels can also be observed in valleys penetrating the interior of mountains.

c) *Terraces and Surfaces Affected by Cryoplanation*

Since during the Quaternary the territory of our country more than once belonged to the region of periglacial climatic morphology, the morphogenesis of these times differed from that of the present age. The conditions of a peri-



FIG. 66. Denudation levels of the Mátra Mountains with a broad pediment in the foreground *T* — Tropical peneplain remnant from the end of the Miocene (Tortonian-Sarmatian), *H₃* — presumed Sarmatian piedmont, *H₂* — Lower Pannonian (Pliocene) piedmont, *H₁* — upper Pliocene pediment which was subjected to further morphogenetic changes in the Pleistocene (*P - Q₁*)

glacial denudation in Hungary and the scale of the then predominating external processes have been dealt with in the course of earlier investigations, too. Kéz, Bulla, Kádár, Láng and Kerekes discussed, in several papers, the mechanism of the rivers and loess formation and gave a general characterization of these processes.

The function of periglacial processes (freezing, solifluction, gelideflation, slope wash) in shaping land surface in the foreland of our hill landscapes and

central mountains have recently been described in detail by Pécsi (1961*e*, 1962*a*). His investigations suggest that in the cold-dry glacial phases with scarce precipitation the evolution of the surface proceeded in an areal and not in a linear way. On soils which were frozen for a considerable part of the year or, at certain episodes, throughout the year the scarce rainfall caused areal denudation of the slopes or areal deposition of talus debris on them. Such climatic conditions led to the transformation by cryoplanation of the landscape abounding in valleys formed in earlier temperate climatic periods. Owing to exposure, to differences in the quality of the rocks and in the thick-

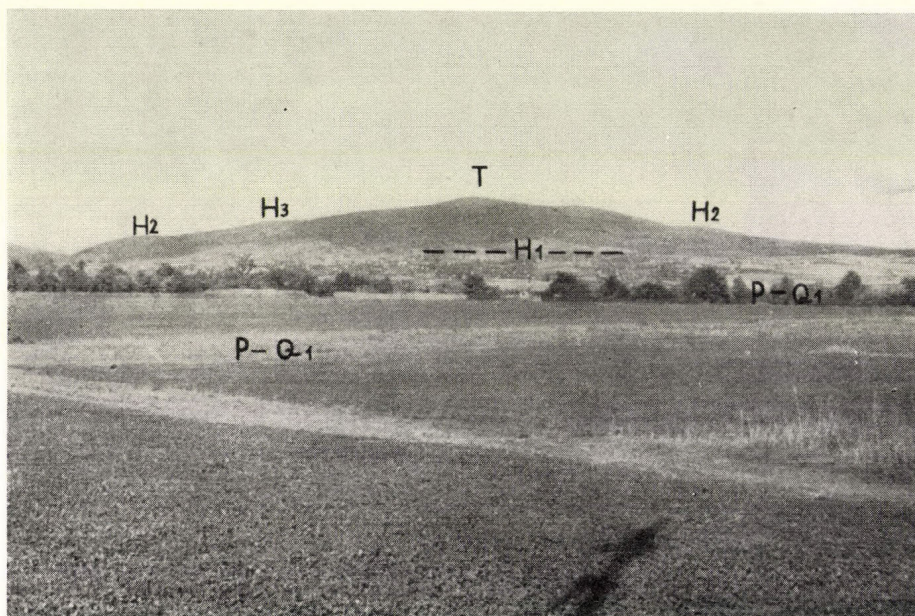


FIG. 67. Wide pediment of the Mecsek Mountains

P - Q₁ — Upper Pliocene pediment which underwent additional shaping at the beginning of the Pleistocene,
H₁ — upper Pliocene pediment, *H₂ - H₃* — presumed abrasion and denudation steps from the end of Tertiary,
T — remnant of a tropical peneplain

ness of the snow cover, the frost penetrated to various depths. Therefore, the denudation of the slopes was similarly disproportionate in cross-section and resulted in derasional and cryoplanational steps. The derasional terraces developed in broad basins and on hill ridges of loose material in the course of the denudation and accumulation of deposits moving to different distances on the slope in an areal manner. On the other hand, under the influence of freezing penetrating to different depths, a series of cryoplanational terraces formed on the sloping surfaces of massive rocks. Additional investigations are necessary in order to explain the origin of these features more fully. For the time being, we are only able to recognize these features and to correlate them with the periglacial processes. Minor benchlands have already been observed

along the Danube (Pécsi 1954) and in the Mezőföld (Ádám, Marosi and Szilárd 1959) also in loose rocks, but their relationship with the periglacial processes was not yet recognized then.

Most of the derasional levels, their number and altitude, and all cryoplanational levels are independent of the local base level of erosion, nor do they indicate the individual phases of the uplift of the hill landscape or of the foreland of mountains, but are chiefly dependent upon climatic — periglacial — processes. The derasional levels of the particular slopes vary in number within the range of 3—7; they differ from the fluvial terraces in respect of several form patterns as well as in the following: they follow the outlines of the features on the slopes of hills and basins; depending on the degree of exposure they are often very extensive, and there are slope deposits on their surfaces (Figs 62—65).

Cryoplanational levels occur on truncated surfaces or on piedmont benchlands. These are steps of unequal heights varying from 5 to 15 m. Their surfaces are commonly covered with stone blocks or rock debris.

Pécsi has disclosed the relationship between the pediment levels of denudation and the highest terraces or levels of derasion-cryoplanation in the Danube Valley. He suggests that the formation of the lower pediment surfaces may be ascribed, when judging by the coarse, unrounded debris covering them, to areal processes taking place under semiarid dry-warm (upper Pliocene) and also under dry-cold (glaciations) climate, similarly to the formations referred to as pediment, glacis, and *Fussfläche* (Figs 66, 67). During the more humid interglacials the lower, extensive pediment surfaces have been dissected by terraced valleys (Pécsi 1961c).

STRUCTURAL FORMS AND RECENT CRUSTAL MOVEMENTS

The investigations carried out by the Physiographic Section have demonstrated by numerous examples the morphogenetical importance of structural elements, fracture lines, faults, trough-like subsidences, and that of the uplifts along tectonic lines. The earlier geographical and geological literature furnishes, in this respect, papers and methods in abundance. The results of our research work support, beyond all doubts, the earlier theory according to which surface-morphological observations can lead, in certain cases, to rather well founded, in other cases only to hypothetical, conclusions concerning the geological and tectonical conditions of a given area (Góczán, Marosi and Szilárd 1954). This statement was confirmed several times by detailed drillings serving the examination of the structural patterns as well as by the geophysical research methods. Therefore, one cannot disregard the structural studies based on morphological evidence which, in certain areas, above all in our block mountains and in their surroundings, may furnish data suitable in many respects for drawing the tectonic pattern of the area and in this way spare the national economy the great expenses of developing a very dense network of deep boreholes necessary for structure-investigating drillings. Our geologists and geophysicists are of the opinion that the geomorphological surveys and methods can successfully be applied in research into the structure of surface levels and deeper horizons, especially in the case of block mountains, smaller basins and borders of plains.

However, we have to mention that in certain cases the objection that certain authors, when characterizing surface features, lay too great a stress on the function of tectonic elements, especially in connection with hill regions made up of loose sediments, is well founded. It was undoubtedly an exaggeration to consider some benchlands as tectonic elements. Criticism against these exaggerations is justified. However, this must not result in restraining us from using the geomorphological survey in the exploration of tectonic elements in the future. Our task is to investigate thoroughly where we have to deal, first of all, with tectonic form elements, and where chiefly with form elements produced by denudation. It is important both theoretically and practically to decide where and to what extent structural elements are removed or accentuated by denudation and what processes are involved. Although, owing to the lack of adequate exposures, it is often very difficult to detect the tectonic lines, on the basis of the dislocation of strata, in the Mezőföld, in the Transdanubian Hill Region and in the borderlands of the Little Plain, still investigations could throw light on the fact that there is a close connection between the structure of the basement underlying the thick Pannonian and early Tertiary beds on the one hand, and the morphological features, especially the valleys and trough-like subsidences, on the other. The NW—SE strike of the rigid

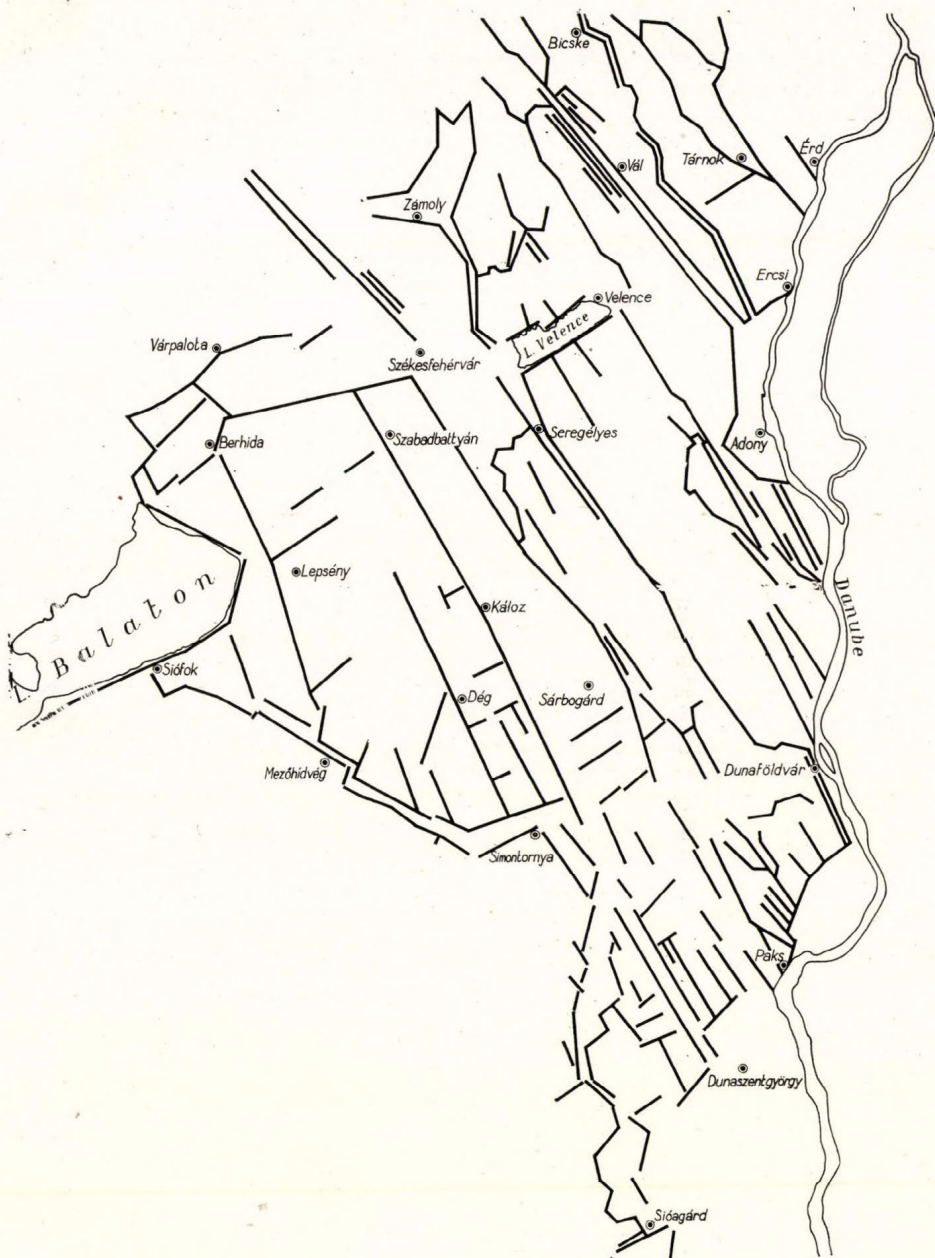


FIG. 68. Tectonic lines and the valley system of Mezőföld, according to L. Ádám, S. Marosi and J. Szilárd (1959)

valleys cut into the surface of the Mezőföld exhibits a close relationship with the tectonic lines appearing on the surface of the adjacent Central Mountains (Ádám, Marosi, Szilárd 1959) (Fig. 68). In cases of fortunate exposures, e.g. in the Érd railway cutting, and in the Upper Pannonian deposits of the larger exposures between Székesfehérvár and Várpalota, the trends of the fracture lines coincide with the morphological features. Similar phenomena have been pointed out in the Somogy Hill Region by Szilárd and Marosi; in the Vas—Zala Hill Region by Somogyi; in the Marcal Basin by Góczán; on the gravel sheet beyond the Dráva by Ádám; in the hill range extending in the northern foreland of the Bakony and Vértes Mountains and in the Danube Valley in several places by Pécsi. On the basis of the exposures it could also be stated that on loose sedimentary rocks fracture lines are denser than it is reflected by the morphological features, as denudation obliterates the morphological traces of less developed tectonic lines. For instance, in the northern hilly foreland of the Bakony and Vértes Mountains and in certain parts of the Mezőföld, the erosional-derasional valleys striking NNW—SSE or NW—SE, while trending towards the Danube, accentuate only the tectonic lines with the above direction, and those perpendicular to them play only a subordinate role.

The results of the investigations directed towards detecting recent tectonic movements are likewise of considerable interest both theoretically and practically. Our research workers have compiled numerous data for a more precise characterization of the formation and the areal delimitation of recent depressions known from earlier geological and geomorphological literature (Bulla, Marosi and Szilárd) for Lake Balaton; Ádám for Lake Velence; Góczán, Marosi and Pécsi for the depressions of the Great Plain, and Pécsi and Góczán for the Little Plain. In addition, our terrace-morphological investigations in the valley of the Danube and of other rivers have provided information about the scale and the time of Quaternary tectonic movements. These data are generally in agreement with those furnished by geophysical and geodetic measurements, and thus they mutually complete each other. The above data together with similar results gained by other geomorphologists (Szabó, Láng, Borsy, Székely) and geologists (Pávai, Sümeghy, Miháltz, Erdélyi, Rónai) have modified the earlier general opinion according to which no important tectonic changes occurred during Quaternary times. The data of our terrace-morphological investigations, together with the relevant karst-morphological and geological investigations, ascertain unanimously that during the Quaternary era the Hungarian Central Mountains were uplifted by about 200 to 300 m. On the other hand, in the Great Plain, though very unequally subsided, we have to reckon with a subsidence reaching in places even 300 to 600 m. In the central part of the Little Plain, i.e. in the Győr Basin, the thickness of the Quaternary fluvial deposits reaches even 150 to 250 m (Pécsi 1956c, 1958b, 1960d).

The data available by geomorphological research methods, permit us to distinguish between three main stages of crustal movements within the Quaternary era: 1. lower Pleistocene — pre-Günz, 2. middle Pleistocene (late Mindel — Mindel—Riss interglacial), 3. upper Pleistocene stage of movement. The early Pleistocene stage of movement we attempted to split into three

phases: *a*) Riss—Würm interglacial phase (Bulla, Pécsi, Ádám, Marosi and Szilárd), *b*) intra-Würm phase (Würm I—II) (Ádám, Marosi and Góczán), and *c*) postglacial movement phase (Bulla, Ádám and Pécsi). The formation of our recent marginal subsidences and larger lake basins is mostly contemporary with these three phases of movement at the end of the Pleistocene.

The Hungarian researchers dealing with Quaternary deposits as well as the workers of the Physiographic Section have, from several aspects, elucidated the fact that the relief of the country had attained its relative altitude chiefly under the influence of the epeirogenetic and tectogenetic movements taking place at the end of the Pliocene and during the Pleistocene. As a consequence of these recent movements and of the increased erosive processes provoked by them, the slopes became bolder during the Pleistocene. The denudation of the slopes caused by uplifting movements proved to be very intensive in the hill and mountain areas of Hungary and was associated with valley formation by erosion during the pre- and interglacials, and with gelifraction, solifluction, pluvionivation and eolian processes during the Glaciations. The processes of denudation which became animated as a result of the uplifts and which during the Pleistocene constantly moulded the relief and the slopes, resulted commonly in juvenile features and sediments.

HYDROGRAPHIC INVESTIGATIONS

The hydrographic investigations were started within our Section as early as the middle of the fifties parallel to, and associated with, geomorphological surveying in the Mezőföld. Since that time these investigations have gone on with increasing intensity.

Since hydrographic compilations require many hydrographic and meteorological data which can be obtained only by analysing the results of observations carried out regularly for years, this work could not be done, and cannot be done even today, without using the data of other institutes. However, in certain respects, as e.g. when estimating the rate of flow of minor streams, and the yield of springs, we have had the opportunity to carry on direct investigations and measurements in the field.

A fairly large hydrographic treatise on the Mezőföld has already been completed (Marosi, Szilárd 1959) in which the streaming and the fluctuations of the subterranean streams, the water regime and the water level oscillations of the running and standing surface waters as well as the trends and peculiarities of drainage of the individual catchment basins are characterized in close relationship with the tectonic features, the structure, the geomorphology, and the climatic conditions of the area.

On the basis of their measurements the authors could describe the regime and the rate of flow of a number of minor streams about which no organizations dealing with water resources have yet had the necessary data, which are so important for drafting plans for the improvement of riverways, for the possibilities of water production, irrigation etc.

During the study of the hydrographic conditions of the Somogy—Tolna Hill Region now under way, not only the above-mentioned data of smaller streams but also those of the major springs will be collected (Ádám, Marosi, Szilárd).

PHYTOGEOGRAPHICAL INVESTIGATIONS

The Physiographical Section of the Geographical Research Institute was joined by a phytogeographer as late as 1960. The necessity of closely connecting the phytogeographical investigations with the physiographical studies was recognized a long time ago. Doing so, we want to enlarge the scope of the monographs dealing with regional landscapes, and to furnish concrete phytogeographical data for studying the close relationship between morphology and vegetation (Jakucs 1962). The fundamental investigations of Jakucs comprise the study of shrub forests of pubescent oak so important for the afforestation of the natural barren landscapes and karst regions of Hungary. In his monograph *Die phytocönologische Verhältnisse der Flaumeichen Buschwälder Südostmitteleuropas* (Jakucs 1961b) on this subject he treated a plant community throughout its geographic realm in Central and South-East Europe (Austria, Czechoslovakia, Poland, Hungary, Rumania, Bulgaria, Yugoslavia).

RESEARCH METHODS

Initially the research work of the Section was based upon earlier experience gained in methodology. We could render our work more effective only because our better potential possibilities permitted us to make rather detailed observations in the field. These, however, were soon found insufficient for urgently assessing formations, which required tests and analyses of the material sampled. The most frequent problem was how to separate fluvatile sand from blown sand. For this sake, the percentage distribution of different grain sizes within the granulometric composition of sand samples and the shape of the grains were analysed. For geomorphological investigations, we started to use the granulometrical methods which had been applied earlier for the examination of sedimentary rocks. Even though the examination of grain size distribution and of the shape of grains in sand samples did not permit us to clarify the origin of the respective samples, in many cases we could still trace the features characteristic of the sandy deposits of different origin (Ádám 1959a, 1959b, 1960).

Szádeczky's roundness-measuring method could be applied much more successfully for the separation of fluvatile gravels belonging to different river systems. It permitted a reliable distinction of the gravelly deposits of different river basins, as well as the differentiation or identification of terraces of different height in the Danube Valley. This method was slightly modified for its more rapid application in field work. The gravels of equal roundness suitable for comparison were entered in photo-plates corresponding to ten degrees of roundness (Pécsi, Pécsi-Donáth 1959, 1960).

The application of these methods permitted Ádám (1959a, 1959b) to separate the gravels of the Mór Fault Trough from those originating in the Bakony Mountains and in the Danube, while Góczán could point out the analogy of roundness of the gravels from Billege in the Tapolca Basin with those of the Danube (1960) and to ascertain the presence of remnants of the gravel sheet of the Rába in the eastern part of the Marcal Basin (1962). In addition, this method proved to be suitable for the characterization of gravels obtained from deep boreholes, too. Thus for instance, the gravel horizons lying at depths of 200 to 400 m in the Danube—Tisza Mid-Region could be traced back to the Danube.

Our work comprised the analyses of the percentage distribution of the mineralogical and petrographical and also of the heavy mineral composition of sandy and gravelly sediments.

In recent years the differential-thermical analysis (DTA) of clay minerals was started in order to separate the clayey and the loamy sediments and formations, to determine the degree of weathering and, by this means, to reveal the circumstances of their formation. This method also furnished supple-

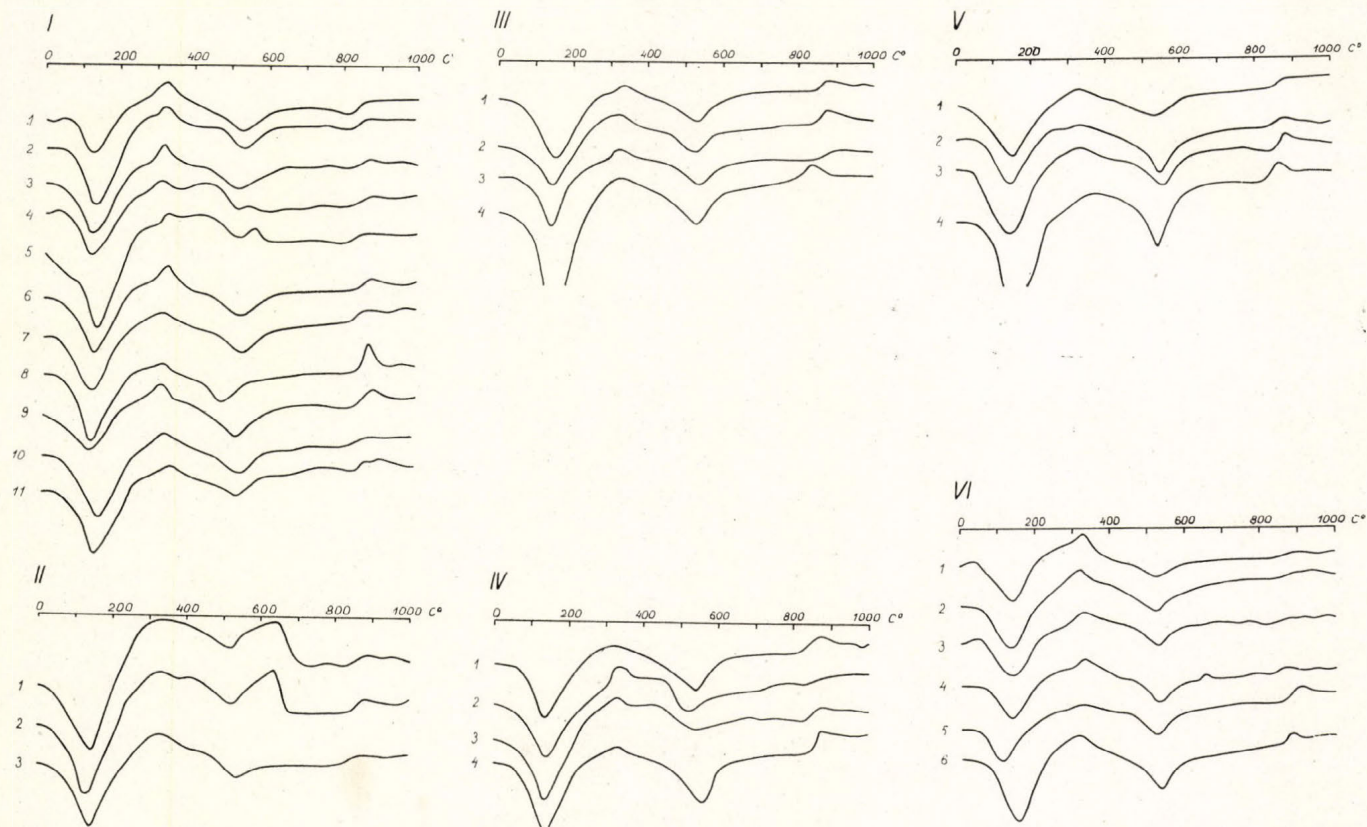


FIG. 69. Clay mineral content of the buried fossil soils in Hungary, on the basis of differential-thermal analyses, according to Pécsi and Donáth

I. Fossil soil ($F_1 - F_9$) zones in the exposure of loesses at Paks: 1 — F_1 3.5–4 m; 2 — F_2 10.5 m; 3 — F_3 13 m; 4 — F_3 14 m; 5 — F_4 16 m; 6 — F_5 22 m; 7 — F_5 23 m; 8 — Tuffit 25 m; 9 — F_6 29 m; 10 — F_7 43 m; 11 — F_8 46–47 m

II. Chernozem soils in loesses: 1 — recent chernozem at Paks, 2–3 — fossil chernozem (Mezőföld, Mende)

III. Fossil brown forest soil in loesses: 1 — Nagymaros (F_3), 2 — Nagymaros (F_4), 3 — North Region of Tisza, 4 — Basaharc (F_4)

IV. Red-brown fossil soils in loesses: 1 — Gomba, Monor Hill Region, 2 — Döbrökőz, Tolna Hill Region, 3 — Paks (F_4), 4 — Szekszárd, Tolna Hill Region

V. Red soil fossil: 1 — Bonnya, Somogy Hill Region, 2 — Velence Mts, 3 — Beleska, Tolna Hill Region, 4 — Vasvár, Kemenes Ridge

VI. Loesses and loess-like sediments redeposited by solifluction: 1 — Paks 6 m; 2 — Nagykanizsa, 3 — Szentgotthard, 4 — Szombathely, 5 — Körömend, 6 — Zalalövő

mentary data for typifying fossil soils according to their genesis (Fig. 69). For differentiation of types of the Hungarian loesses and for the solution of their genesis questions, we applied the methods of loess analysis (Fig. 70); (curve of the granulometrical distribution, determination of the lime content, coefficients of settling, yield point etc.) used in sedimentology and in soil mechanics (Ádám, Marosi, Szilárd, Pécsi).

These methods were borrowed from geology and mineralogy-petrography. Other quantitative methods were also used for geomorphological investigation. In recent years we started detailed measurements of the angle of slope (Pécsi, Székely, Szilárd) to typify and characterize the dells and the erosional-derasional valleys of complex genesis and slopes in general. The frequent measurements of the angle of slope permitted us to obtain accurate cross-sections of valleys, of slopes and to determine the gradient curves of the smaller valleys along the slope. By applying this field method, we intend to start the slope-morphological investigations satisfying even practical requirements to which little attention had been paid in the earlier period. The observations made hitherto suggest that the results of slope-morphological investigations would permit us to characterize the so-called equilibrium slope — showing little degradation — for each particular kind of mother rock and for a certain relative altitude. We want to enrich the fundamental principles of research into soil erosion by means of these investigations.

For the last two years we have striven to complete our geomorphological research, in particular the analysis of the relief, by applying, besides merely geological and geomorphological methods used before, soil-geographical, phytogeographical and climatical methods. The value of the results obtained during our research work has been increased both theoretically and practically by the fact that increasing attention is being paid to the results of soil geography and palaeopedology (Pécsi, Góczán). Among the processes shaping the surface of the earth, the role of fluvial erosion, deflation, and the crustal movements were analysed quite fully, while the processes of soil formation were somewhat neglected. Nevertheless, the diverse types of soils already formed and the knowledge of the circumstances of their formation would permit us to draw very important conclusions concerning the development of the earth's surface.

Certain soil types, e.g. clayey forest soils, have rendered possible the effective slope-degrading activity of periglacial solifluction to proceed on the slopes of our hilly and mountainous regions, even on rocks in which the clayey fraction was lacking or was very subordinate (loess, pebble, debris etc.).

Although the application of the results and methods of the phytogeographical investigations is now only in its initial phase, these first steps have proved very successful. For instance, in the wide flood plains of our rivers the morphological methods permitted only a rough distinction between the flood plain horizons, while the analysis of plant ecology has enabled us to subdivide them more exactly and to satisfy thereby practical demands. By means of the plant communities consisting of subassociations, both deep-seated and high-seated flood plain horizons can be split into several habitats (Kárpáti, Pécsi 1959, 1962) (Fig. 8).

P. Jakucs has dealt thoroughly with the features of vegetation in the Transdanubian Hill Country. The natural vegetation of this territory (forests, meadows, bogs etc.) is being studied by combined research methods (coenological analysis, microclimatic measurements, soil test etc.), including the description of the secondary vegetation. The area in question belongs mostly to the zone of oak forests and hornbeam-oak groves, yet its vegetation has been transformed into a variegated mosaic by the geomorphological conditions (slopes, valleys, basins, mountains etc.), by the features due to the variety of bedrocks as well as by the civilization. This treatment is achieved by the exploration of the area and by a completely detailed surveying of its parts. Namely, the regularities observed in well-selected minor model areas can always be generalized for the major areas surrounding them.

While studying the development of the earth's surface, the individual types of forms, especially the minor valleys, ravines and gullies, and the degree of soil erosion, we have taken into account not only the phytogeographical data, but also the results of climatology, more precisely the distribution of the climatological elements in time and space, as well as the types of the present and the past climates. Nevertheless, it is believed that the morphogenetic role of the types of palaeoclimates can be interpreted correctly only if a regular survey of the palaeoclimatic elements (Bulla 1960, Pécsi 1961*b, e*, Somogyi 1961) is carried out in the future.

In developing geomorphological research methods, we have also tried to adapt them to investigations in cognate sciences, and we did not fail to achieve some success. In this connection a number of examples and data were furnished by Ádám, Marosi, Szilárd, members of the Section (tracing tectonic lines and fractures on the basis of morphological data). Recently, the application of terrace-morphological methods enabled us to provide sufficient evidence on the time and the scale of recent crustal movements and to outline the areas most endangered by earthquakes (Pécsi 1956*a*, 1958*b*, 1959*b*, Somogyi 1956) (Fig. 71). It could be pointed out that earthquakes have been most frequent in tectonic zones where synchronous terraces or recent deposits have undergone most intensive deformation and dislocation for a relatively long geological time. Such places are indicated, for instance, by the deep burial of the deposits of fluvial terraces in the southern part of the Pest Plain, and by the step-like faulting of the Danube terraces between Komárom and Dunaalmás etc. (Fig. 1).

The methods of geomorphological survey have proved to be suitable for pedogeographical and phytogeographical investigations too. A good example is given in the chapter on the Holocene alkalization process (formation of alkali soils) in the dissertation of Somogyi (1960).

When analysing the evolution of Hungary's river drainage during the Holocene, Somogyi found that the great extension of the alkali soils in Hungary could not be ascribed only to the climatic factor, regarded earlier as fundamental, but rather to such conditions of geological development, tectonics and hydrology of the Hungarian lowland basins as have provoked accumulation of salts. The recent soil-geographical investigations carried out by Soviet and Hungarian workers in order to clarify the genesis of the alkali soils have not only thrown light upon the chronologico-geographical oscillations of the

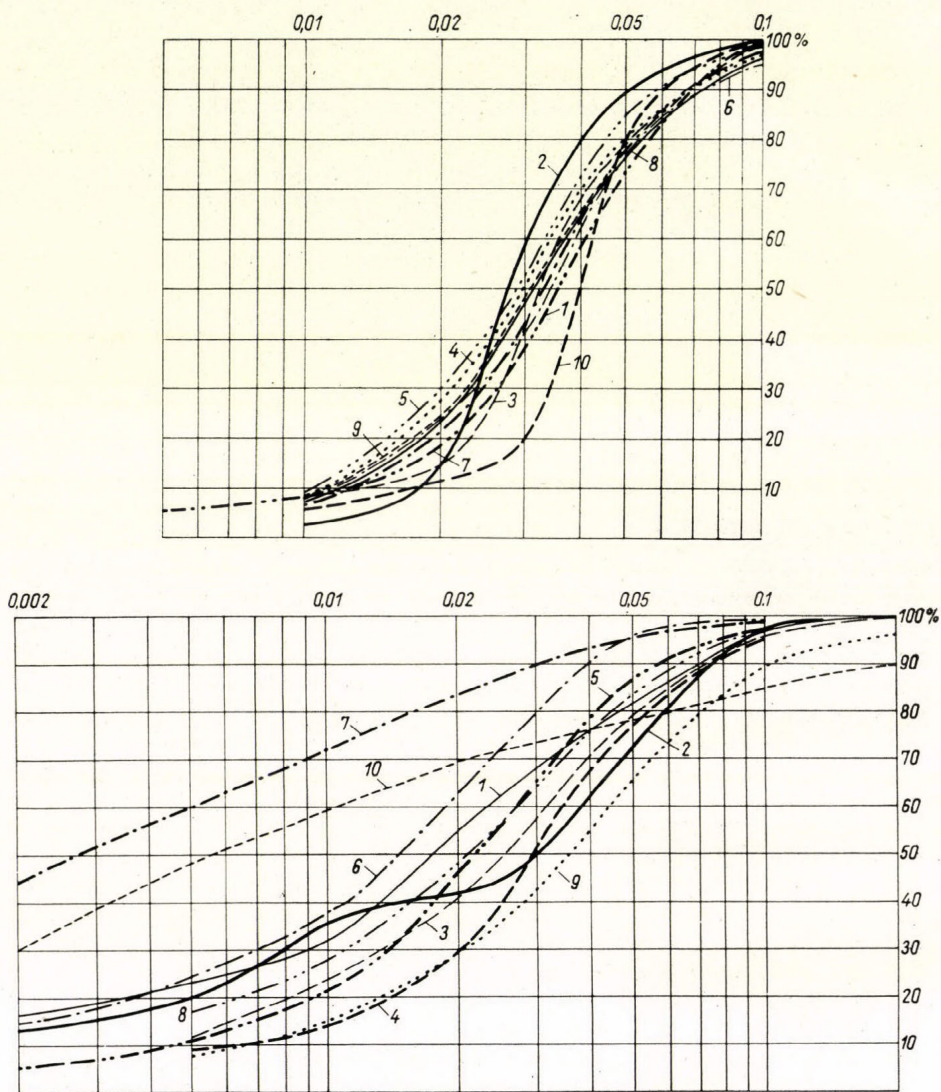


FIG. 70/a. Granulometric curves of the Hungarian loesses and loess-like sediments

I. Eolian loesses: 1 — Vác DCM 2 m; 2 — Dunaújváros 4 m, 3 — Dunaújváros 10 m, 4 — Dunaújváros 4 m, 5 — Dunaújváros 5 m, 6 — Paks 8 m, 7 — Paks 6.8 to 7 m, 8 — Paks 7.8 to 8 m, 9 — Paks 9 to 9.2 m, 10 — Paks 1.6 to 1.8 m

II. Fluvial loess-like sediments: 1 — Szolnok 2 — Kúnszentmárton, 3 — Ceglédbercel 1.5 m to 2.5, 4 — Paks 24.2—25.7 m, 5 — Paks 26.9 to 27.9 m, 6 — Vámosgyörk 2 to 2.2 m, 7 — Tószeg 8.5 to 10.1 m, 8 — Kocsér 1.6 to 3.2 m, 9 — Vác DCM 5 m, 10 — Törökszentmiklós 5 m

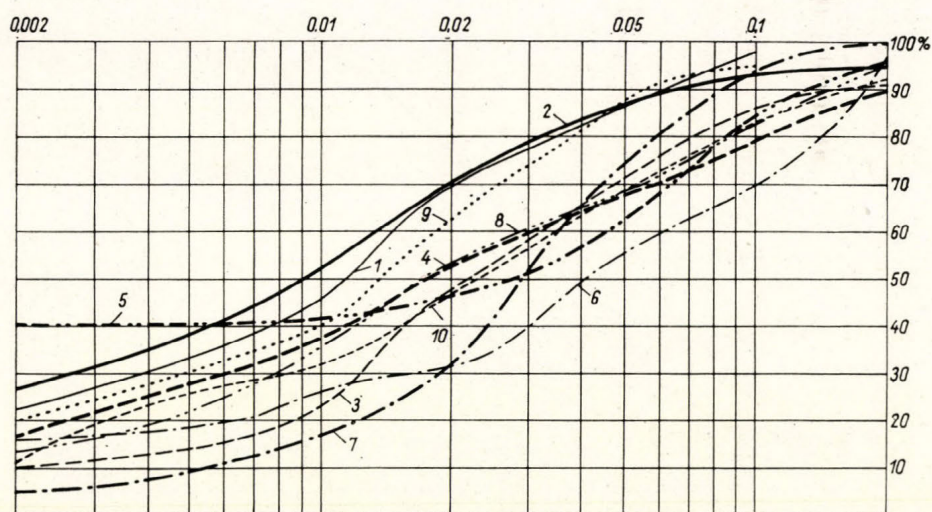
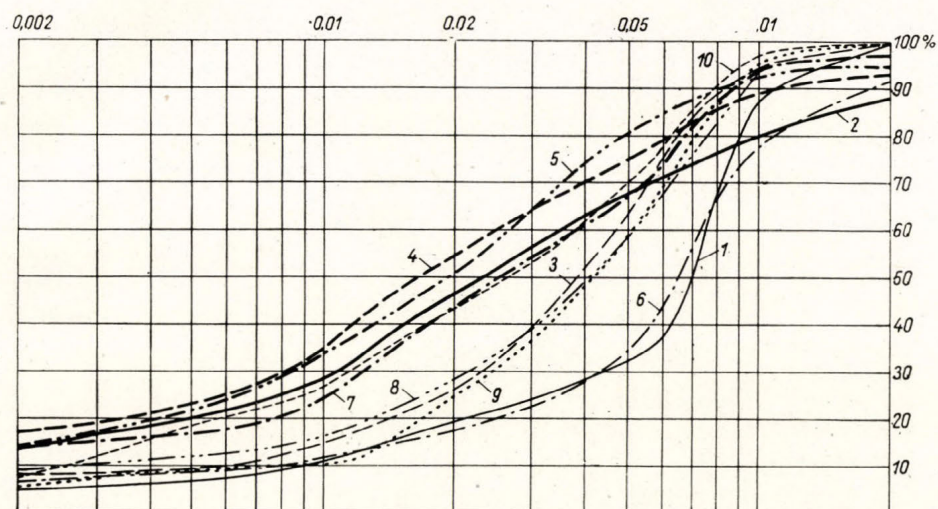


Fig. 70/b. Granulometric curves of the Hungarian loesses and loess-like sediments

III. Slope loesses: 1 — Balatonberény, 2 — Nagykanizsa, 3 — Tolnanémedi, 4 — Pécsvárad, 5 — Béngye 3 m, 6 — Paks 15 m, 7 — Basaharc, 8 — Gamás, 9 — Kötse 2.5 m, 10 — Bakonybél
 IV. Slope loess loams: 1 — Körmend, 2 — Vasasszonyfa, 3 — Egyházásrádóc, 4 — Vép, 5 — Tiszadob 5 to 5.9 m, 6 — Mátészalka, 7 — Vác DCM 1 m, 8 — Szombathely, 9 — Nemeskölta, 10 — Lőcs-Bő

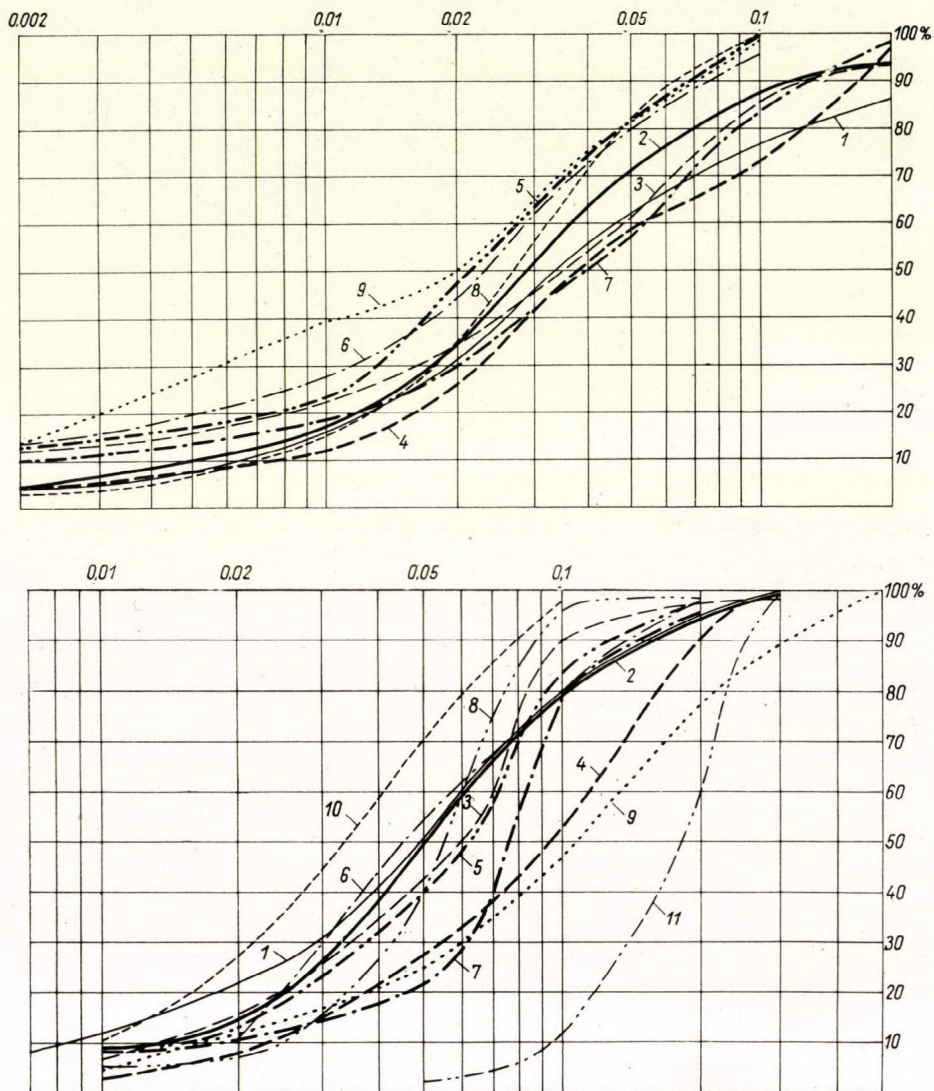


Fig. 70/c Granulometric curves of the Hungarian loesses and loess-like sediments

V. Fossil soils in loesses: 1 — Vác DCM 7 m, 2 — Paks 9.6 to 10.8 m, 3 — Paks 11.8 to 12.2 m, 4 — Paks 20.5 to 21.5 m, 5 — Paks 43.2 to 43.4 m, 6 — Paks 43.7 to 44.2 m, 7 — Vác DCM 8 m, 8 — Vác DCM 6 m, 9 — Szulimán

VI. Sandy loesses, loessy sands: 1 — Cegléd 1.7 m, 2 — Kecskemét, 3 — Kecskemét 5.4 m, 4 — Kiskunfőlegyháza 3.5 m, 5 — Nyíregyháza 2 m, 6 — Orosháza 2 m, 7 — Vác DCM 4.6 m, 8 — Dunaújváros 18.6 m, 9 — Paks 15.4 to 15.5 m, 10 — Paks 1.8 to 2 m, 11 — Jászberény 3 to 3.9 m

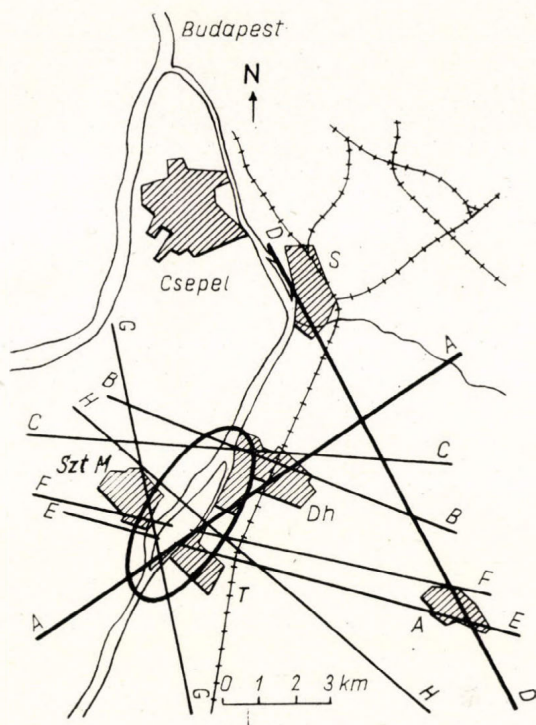


FIG. 71. Lines of the major surface cracks and fissures as observed after the earthquake near Budapest, 12 January 1956. According to Somogyi A — Alsónémedi, Dh — Dunaharaszti, S — Soroksár, Szt. M. — Szigetszentmiklós, T — Taksony; A—A, D—D — the lines of the cracks; B—B, C—C, F—F, G—G, H—H — seismic trends and strikes of minor cracks in the soil. The area marked with an ellipse is the supposed epicentre where the earthquake reached an 8th degree of intensity

character of alkalization of the soils but have also led to the conclusion that the various types of alkalization constantly exist in close juxtaposition and may have existed also in the past. The examination of the role and of the effect of the creating and influencing agents enables us to analyse the regional changes in alkalization.

GEOMORPHOLOGICAL MAPPING (SYNOPTIC GEOMORPHOLOGICAL MAP OF HUNGARY)

a) *Development and Objectives of Geomorphological Mapping in Hungary*

Recently geomorphological mapping chiefly for the purposes of land utilization and planning has come into the fore. This allows a wider practical application of the results achieved in physiographic investigations, more precisely in geomorphology. In geomorphological maps the physiographic environment, especially the elements of the relief, its constitution and the trend of its development in time and space can be simultaneously represented, depending on the type and the scale of these maps, while in description all these items can be given and characterized only in succession resulting in a lengthy discussion.

The necessity of representing the forms of relief on maps on the basis of genetic principles arose in Hungary some ten years ago, shortly after the detailed physico- and economico-geographical survey of Hungary was started in 1950 within the scope of scientific work scheduled by the Hungarian Academy of Sciences. These investigations were carried out by the geographers of the geographical departments of the Hungarian universities, the Transdanubian Scientific Institute, and the Geographical Research Institute of the Academy, founded in order to perform the bulk of the work and to co-ordinate it. The institutions involved received considerable financial support from the Academy.

Beside general subjects, the physiographic research workers investigated the geomorphology of the individual regions and their parts. The results of these studies were published in the form of essays and regional monographs. Practical life (regional engineering and economico-geographical planning) soon required the completion of the geomorphological descriptions and partly their substitution by detailed maps and profiles to increase the perspicuity and applicability of the material.

At the beginning, in the geomorphological treatises individual phenomena or groups of identical features were represented on map (for instance, maps of terrace morphology, of karst morphology and of denudation levels. The geomorphological mapping of each particular landscape unit as a whole, with all its features, took place only later when the detailed geomorphological or physiographical treatment of the individual landscapes had also been accomplished.

In initial geomorphological mapping we were greatly assisted by such works as A. Y. Spiridinov's *Geomorphological Mapping*, the paper presented by M. Klimaszewski during his study tour in Hungary in 1953, and the report on an analogous subject delivered by R. Galon in 1955 in our country. In addition, we used the geomorphological maps published by Soviet, Polish, German,

French and Swiss specialists. Some regional geomorphological maps were prepared on individual initiative (Ádám, Marosi, Szilárd 1959, Pécsi 1959a, Borsy 1961), yet the legends on them and the principles and methods underlying their compilation were not uniform.

On the basis of the experience obtained by these initiatives, the geomorphologists of the Geographical Research Institute of the Hungarian Academy of Sciences under the guidance of M. Pécsi elaborated, in 1960, a project for the preparation of the synoptic geomorphological map of Hungary, considering the frequent claims of practical life. Possibilities for this project were provided by the fact that during the previous ten years Hungarian geomorphologists had surveyed most of the country by individual landscapes. Furthermore, the achievements abroad were also taken into consideration. The draft legend prepared by the GRI was discussed together with the geomorphologists from various universities, with the representatives of the cognate disciplines and those of the designing agencies with a view to complying with their claims and points of view.

b) *Conception and Legend of the Synoptic Geomorphological Maps of Hungary*

The conception, content and legend of the synoptic geomorphological map of Hungary were widely discussed by the workers of the GRI with due regard to similar maps previously published in Hungary and abroad. The preparations were started on the basis of the following principles.

On the genetic geomorphological map of Hungary the following items are represented: I. types of the combined genetic form families (plains, mountains), II. individual genetic forms, III. major formations constituting the surface features, such as the substrate on which the forms have come into being, IV. processes producing surface features and formations, V. the age of the surface features. Our geomorphological map contains, in addition, the more important orographic, morphometric and hydrographic elements of the relief.

The next task was to find suggestive means for representing the rich content of our map. Our present draft explanation is not yet considered to be final.

For the cartographic representation of the manifold content of our geomorphological map, the colour signs of the more important rock suits making up the relief are also used to indicate the processes which had produced the lithological formations. This principle makes the map more easy to read and, at the same time, reflects the trend and dynamism of morphological evolution.

1. The main colours used are

bluish-green	for surfaces and formations brought about by fluvial accumulation,
yellowish	for surfaces and formations with eolian accumulation,
brown-ochre	for deluvial sediments redeposited on slopes in an areal way (derasion),
vermilions	for formations produced by volcanism,
carmine	for the deep-seated magmatic and metamorphic rocks of the palaeomountains.

2. The colours, striped or hatched along the slope, indicate surface-modelling processes

bluish-green stripes	indicate slopes formed by erosion,
brown stripes	indicate slopes shaped by derasion,
orange stripes	indicate slopes shaped by deflation,
black stripes	indicate polygenetic slopes,
red stripes	indicate slopes produced by tectonic movements.

(i) REPRESENTATION OF COMPLEX FORM FAMILIES

In representing the complex form families, the morphological conditions of Hungary were only considered. The surface form families of Hungary can be divided into two major groups, i.e. the group of the planated surfaces, plains, and the groups of different mountain types. The plains are classified in three groups according to the processes that had prevailed in producing them.

Types of Plains

a) We have distinguished alluvial plains and alluvial fans. Both are perfect plains, belonging to the flood plains of the present rivers. These plains are modelled decisively by fluvial accumulation even at the present time. The plains formed by fluvial accumulation are marked in greenish-blue colour. About ten kinds of formations (lithological differences) are shown within this category.

b) The second type of plains comprises the alluvial plains covered by eolian deposits and the planated platform-like plains. Our plains covered by eolian formations emerge above the alluvium of the rivers, frequently rather high, though nowhere above 200 m. These plains are marked by three shades of yellow for three kinds of formations. The platform plains in this category (chiefly in the area of the Transdanubian Hill Region) have locally been divided into flat hill ridges, their slopes being covered by various, loose slope deposits.

c) A separate category consists of levelled plains and alluvial plains denuded by various agents: the deposits formed previously by fluvial accumulation, or the older loose sediments of the Tertiary system had been removed by fluvial erosion, deflation or derasion. This category does not include the peneplain surfaces of the mountain ranges with restricted extension nor their truncated pediments. The latter have been referred to the individual genetic forms.

Types of Mountains

a) The first group consists of volcanic hills and the peneplaned volcanic mountains. There are two types of rocks, i.e. lava and tuff, including their various rock facies. The types of volcanic rocks are, for the most part, marked in vermilion colour suggesting the prevalence of volcanic influence in their genesis. On each particular mountain block the peneplain surfaces and pediments are represented as individual morphological elements.

b) The category of the peneplaned faulted (folded) blocks and block mountains comprises the Hungarian block mountains made up chiefly of Mesozoic limestones and dolomites. This mountain type is marked in violet within which four principal rock types are distinguished (dolomite, limestone, marl, sandstone).

c) The category of the ancient peneplaned blocks and block mountains includes the ruined remnants of the old Variscian Massive. They are indicated in carmine colour which also represents their substrate, the abyssal magmatic and metamorphic rocks, too.

On the individual portions of the peneplaned block mountains belonging to the last two categories the peneplain surfaces and the pediments are indicated by special marks.

(ii) REPRESENTATION OF GENETIC FEATURE ELEMENTS

In the representation of the genetic features, we have distinguished those produced by accumulation, those shaped by denudation, as well as tectonic and anthropogenic features. For the features shaped by fluvial accumulation we have continued to use bluish-green colour added to symbols, while for the features shaped by eolian accumulation, the yellow colour has been used. The features and sediments due to accumulation by derasion are generally marked in brown.

Black symbols are used for the denudation features caused by derasion, erosion and deflation, for the karstic features as well as for the surfaces of denudation and peneplanation. On the detailed geomorphological map these processes are indicated by different colours. The eroded banks, however, are indicated by bluish-green colours. The symbols designating the individual features have been selected in a way to reflect truly the respective features on map.

The tectonic forms are in general shown in carmine, while the anthropogenic ones are marked in black and orange-brown.

(iii) REPRESENTATION OF SLOPE MORPHOLOGY

The processes which had modelled the surface features and the slopes are represented by stripes in different colours running along the slopes.

The state of the slopes is also indicated: slopes being formed and degraded in general, slopes being degraded and dissected by erosional or derasional valleys as well as rocky slopes, slopes affected by slumps and slip-off slopes are distinguished.

The degrading slopes of different genesis may be articulated by dells and erosional ravines and gullies. It may occur, for instance, that dells appear on erosional slopes or terrace edges.

Such a method of representation of slopes also permits us to give detailed information on the petromorphological properties of the surface formations as our legend includes six types of different slope sediments which often cover bedrocks. At the same time, we can provide information on the genesis of the slopes as well as on the peculiarities and trends of the processes which took place during their formation and have continued to act since.

(iv) DENOTATION OF THE AGE OF SURFACE FEATURES

The age of the surface features is marked by capital letters as adopted in the geological literature. In the development of the relief of Hungary since Tertiary times, we have distinguished 14 surfaces of different age and the features associated with them. This method seems to give sufficient information on the age of formation and its features, without overburdening the map with colouring or surface striping.

The distribution of the letters marking age provide adequate information about all the important surface portions.

(v) OROGRAPHIC AND HYDROGRAPHIC ELEMENTS

The orographic and the hydrographic elements are represented on the general geomorphological map of Hungary by contour lines plotted at intervals of 50 m altitude. In addition, four categories have been established for denoting morphometrically the relative differences in elevation (differences in elevation

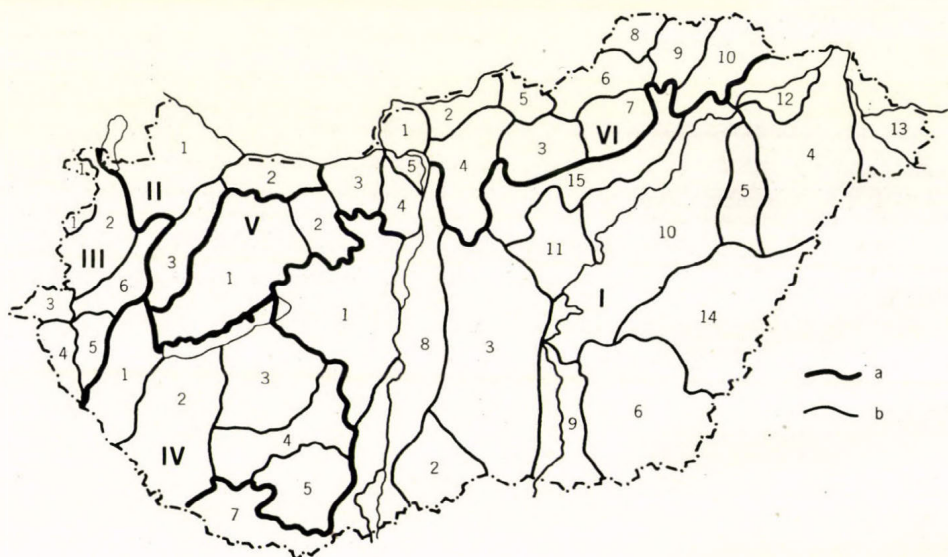


FIG. 72. Landscapes of Hungary

a — Boundaries of major landscapes, b — boundaries of medium landscapes

I — Great Plain: 1 — Mezőföld, 2 — Bácska loess platform, 3 — sandy Ridge of the Danube—Tisza Mid-Region, 4 — Nyírség, 5 — Hajdúság, 6 — Maros—Körös Mid-Region, 7 — Dráva Region with Ormánság, 8 — Left Riverain of the Danube, 9 — Lower Tisza Region, 10 — Middle Tisza Region, 11 — Jászság (Zagyva Basin), 12 — Bodrogek with Rétköz, 13 — Szatmár-Bereg Plain, 14 — Körös Region, 15 — alluvial slope on the northern part of the Great Plain

II — Little Plain: 1 — Győr Basin, 2 — Győr—Tata Terrace Region, 3 — Marcal Basin

III — Subalpine Region: 1 — Sopron and Kőszeg Mountains, 2 — Gravel Sheet in the Trans-Rába Region, 3 — Vas Ridge and Lower Őrség, 4 — Western Zala Hill Region (Hetés and Kerka Region), 5 — Göcsej, 6 — Kemeneshát

IV — Transdanubian Hill Region: 1 — Eastern Zala Hill Region, 5 — Island Mountains of Baranya

V — Transdanubian Central Mountains: 1 — Bakony Mountains, 2 — Vértes and Velence Mountains, 3 — Gerecse Mountains, 4 — Buda and Pilis Mountains, 5 — Visegrád Mountains

VI. Central Mountains of North Hungary: 1 — Börzsöny Mountains, 2 — Nógrád Basin, 3 — Mátra Mountains, 4 — Cserhát, 5 — Karancs and Medves, 6 — Sajó Basin, 7 — Bükk Mountains, 8 — Aggtelek Karst, 9 — Cserhát, 10 — Zemplén Mountains

of the relief under 20 m; 20 to 50 m; 50 to 100 m; over 100 m). These differences are represented by orange-coloured, dotted, broken lines, or by thin and thick continuous lines of the same colour.

The hydrography consists of rivers, of all canals, lakes, marshes and of the important major springs.

Height data which might be important for orientation and for the morphological forms are indicated, and the boundaries of the settlements are schematically plotted.

The manuscript sheets of our synoptic map which is being prepared on the basis of the principles and methods outlined above have a scale of 1 : 100,000. They have occasionally been reduced to the scale of 1 : 200,000.

The draft manuscripts of the geomorphologists have been plotted partly on scale 1 : 75,000, partly on scale 1 : 100,000. The geomorphological manuscript maps of the Danube—Tisza Mid-Region, the Nyírség, the Little Plain and the Transdanubian Hill Region have been completed (Fig. 72).

Furthermore we plan to represent the age of the surface on a separate map by using the above-mentioned data. We intend to plot this map by associating the age indications with the trend of morphological evolution which would illustrate the degradation of the surface as well as its aggradation. This map would also serve as a basis for plotting the scheduled map of soil erosion.

At present, the detailed geomorphological mapping (1 : 25,000, 1 : 10,000) and the preparation of model map sheets are under way, and the detailed mapping of soil erosion is being started.

The fundamental principles of detailed geomorphological mapping roughly correspond to those of the preparation of our synoptical geomorphological map, but its legend is, of course, considerably more ample.

INVESTIGATIONS INTO THE MORPHOGENETICAL EVOLUTION

a) *General Examination of Morphogenesis*

During the last decades the backbone of physiographic investigations has been the research into the development of the earth's surface. Morphogenetics has been the strongest branch of physical geography and geomorphology not only in Hungary, but also abroad. The fundamental method of research into surface evolution based upon the new discipline of climatic geomorphology was developed in our country by Béla Bulla in the early fifties (Bulla 1954—1956). His theory which he called dynamico-evolutional, comparative-functional, dialectic geomorphology and his method of investigation have exerted a decisive influence on research. According to his theory, the development of the relief is neither cyclic, as suggested by Davis's theory of the cyclic recurrence of erosion, nor does it consist of ascending and descending quantitative changes, as supposed by W. Penck, but is necessarily a rhythmical process. Although emphasizing that Davis's theory at this time represented a progressive development by first introducing the theorem of the constant evolution of the surface relief, B. Bulla considered Davis's theory unacceptable, irrespective of its other shortcomings, because it was essentially antidialectic. Davis assumed the normal denudation to involve cycles having invariably the same course and resulting in every case in identical phenomena. Bulla objected to the finalist teleological attitude of Davis's theory. In the terms of this theory, the normal denudation would almost consciously "tend" to denude the elevated palaeosurface down to the base level. Bulla laid stress on the fact that the feature-producing and modelling activity of the forces of denudation was not controlled by any tendenciousness.

He likewise criticized W. Penck's theory which interprets the development of the relief, and relies after all, on Davis's teleology. In his paper *Die morphologische Analyse* Penck (1924) also sets forth his finalist approach. Although Penck started from the true fundamental law that the surface relief is the result of an interaction between the external and the internal agents, the only external agent he considered was the fluvial erosion. Whereas Penck was right in recognizing that all the mountain ranges of the Earth, from the Poles to the Equator, are manifestations of step-like peneplanation, he inferred from this fact that peneplanation did not depend upon climatic zonation but was the result of the aggregate effect of all the denudational agents and of the epeiro- and dictyogenic uplifts. Bulla has pointed out that Penck considered the development of the surface to consist of simple quantitative changes, and, as testified by his work *Die morphologische Analyse*, never realized that these turn into qualitative changes.

Bulla's theory of the rhythmical development of the surface can briefly be summarized as follows: 1. The variation of the relief is a constant, dialectic self-development; 2. The development is not teleologic, but is determined

by the total work of the internal and the external forces initiating and influencing either strengthening or counteracting one another, i.e. dialectically changing in space and time; 3. The rhythmic succession of the stages of development, differing both quantitatively and qualitatively, i.e. the supersession of the decaying forms by new developing forms and the accumulation at the quantitative changes into qualitative ones generally set in suddenly but are not explosion-like. The major forms of the relief (mountains, stepped landscapes, basins, valleys) are the result of a rhythmic development over a long period pregnant with dialectical contradiction.

On the basis of the rhythmical development of the geographical mantle, the general laws of relief evolution have also been formulated by Bulla: "a) The constantly and rhythmically changing relief forms are in qualitatively different stages determined by the qualitative relationships between the external and internal forces, by the duration of their activity, by the lithological properties of the rocks and by their areal extension. b) The rhythmical process of morphogenetical evolution depends on the interaction of the rhythmical endogenic movements and climatic changes. c) Hence, the Earth's surface evolves in rhythmically changing climaticomorphological regions, being superimposed on major structural forms again of rhythmical development. d) In their evolution, the individual major structural forms (massives, orogens, unstable shelves, stable shelves) exhibit qualitatively diverging sculptural patterns in the various climatic morphological regions, although their structures are identical."

b) Stages of Morphogenetical Evolution in Hungary since the Late Tertiary

Relying on the geological and geomorphological investigations, Bulla has tried to confirm his theory of the rhythmical surface evolution by taking examples from the formation of the relief in Hungary. He has analysed the rhythmical development of the relief in Hungary since the Late Tertiary. According to him the Miocene is the period from which the structural and climatic rhythms controlling the evolution of the geographical mantle can be revealed even in Hungary by an analytic and comparative study of the surface features. In Hungary there are, of course, pre-Miocene structural forms, too, but no pre-Miocene forms produced by destruction and accumulation are available. The evolution of the country relief is divided by Bulla in six rhythmical stages.

The first stage of geomorphological evolution considered to have begun with the Miocene is the period of areal denudation which succeeded the Savian orogenic phase. During this stage the geographic cover was characterized by the following features: epeiro- and dictyogenic upheaval, uniform mainland in Transdanubia, vast mainland in the north and the north-east. The climate was semitropical, humid. The relief developed by areal denudation and peneplanation processes, the proof of which can be found in the Kőszeg, the Sopron and the Mecsek Mountains and the Transdanubian Central Mountains. The formation of semitropical tower karst features and of truncated-karsted surfaces can be observed, first of all, in the Bükk Mountains and in the Aggtelek Karst.

The second stage took place in the Helvetian–Tortonian times of the Miocene. This stage is characterized by faults in the Mecsek Mountains (Styrian movements), by the disintegration of the mainlands which had existed during the Lower Miocene, by the transgression of the sea and its archipelagic character. Development of andesite volcanism, of volcanic mountains. Formation of peneplain surfaces in the block mountains. Climate: semitropical. Formation of gravel sheets in the Bakony, Sopron and Mecsek Mountains. The second stage comprises even the Sarmatian.

The third stage took place in the Lower Pannonian. It is characterized by the over-all transgression of the sea (inundating the largest part of the country), by intensive denudation throughout the mainlands (peneplanation during the Pliocene even in the volcanic mountains of Hungary). Climate: exhibiting Mediterranean features with corresponding natural vegetation and soil formation (red clays).

The fourth stage took place in the Upper Pannonian. It is characterized by over-all upheaval, disintegration by faults of the gradually uplifting portions of the truncated-block mountains, differentiation of the basins of the Great Plain and of the Little Plain, basaltic volcanism (Rhodanian phase). Climate: temperate. Character of evolution of the relief: linear erosion (valley formation), karsting of temperate zone type.

The fifth stage took place in the upper Pliocene. It is characterized by the continuation of the over-all upheaval, disappearance of the sea, formation of inner lakes, fluvial accretion of the lowland basins, formation of the Palaeo-Danube and the system of its tributaries, by the erosional incision of the Pannonian relief of Transdanubia and of the northern basins. Climate: gradually cooling. Character of evolution of the relief: deepening of valleys, degradation of slopes in the mountains, fluvial and lacustrine accretion in the lowlands and basins.

The sixth stage took place in the Pleistocene and the Holocene. It is characterized by tectonic fault disturbances (Rumanian–Baku phase), unequal uplifting of the block of the Central Mountains, by the additional sinking of the central part of the Little Plain, of the marginal troughs and of the central and eastern portions of the Great Plain. Climate: rhythmical alternation of the glacial, antiglacial, subarctic and oceanic types. Accordingly, during the glaciations the territory of Hungary underwent a morphogenetical evolution characteristic of the periglacial region exhibiting features of loess formation and glacial loam formation, solifluction, periglacial stone fields, accretion of valleys, and restricted karsting of limestone surfaces. In interglacial times: temperate type degradation of slopes, deepening of valleys, incision of terraces in valley bottoms which had been covered by pebbles and gravels. In postglacial times: slight deepening of valleys alkalization in the Great Plain, widening of the flood plain of rivers, formation of blown-sand areas and sand forms. The present patterns of the hydrography also took shape at these times.

Bulla's statements, published in 1956, about the general evolution of the relief of Hungary can be completed with some remarks relying on the basis of recent investigations. In Hungary's Mesozoic and Paleozoic block mountains, climatic conditions suitable for the formation of surfaces truncated under the

effect of semitropical areal denudation may have existed as late as the Miocene. This process appears to have extended well into the Lower Pliocene, but in the Upper Pannonian and the Upper Pliocene (in the course of the fourth-fifth stages), traces of the formation of pediments (*Fussflächen*) can be observed. The marginal piedmont benchlands and pediments of our Central Mountains are thus no simple products of block faulting of our former peneplaned block mountains, which would have been brought about by the overall upheaval starting at the end of the Upper Pannonian as interpreted formerly by Bulla (1956a, 1958). On the other hand, the study of the sixth stage has revealed the existence of several climatic types. As regards the times during which the cold-dry climatic types of the glaciations were developed, we ascribe a relatively greater surface-shaping role to cryoplanation, as inferred from the general spread of the cryoplanation horizons, derasional horizons and formations as well as from that of the periglacial slope deposits (Pécsi 1962f).

It is quite evident that the derasional processes were not the only and principal factors modelling the relief of Hungary, because the periglacial climate lasted only for a small fraction of the Pleistocene. During the predominance of the non-periglacial climatic types the role of erosion, i.e. of valley formation was definitive, and since erosion acted for a longer time, the valley landscape has remained characteristic in our mountainous and hilly areas. Although the processes of fluvial erosion were thoroughly studied, little information on the surface-shaping function of the derasive processes has been obtained. Its importance is emphasized by the fact that during the last glaciation this process was a decisive modelling agent and, owing to the relatively short time that has elapsed since then, the relief in many places has preserved both forms and sediments testifying to this fact. In addition, certain processes of derasion are active even today and exert a pernicious effect especially in our slope areas subjected to tilling. Therefore, the knowledge of the development and the laws of these processes is important for practical purposes.

GEOMORPHOLOGICAL EVOLUTION OF THE INDIVIDUAL REGIONS OF HUNGARY

Beside research into the history of the development of the surface, the examination of the evolution of the individual regions of Hungary has been the main and concrete task in our research work. These investigations were carried out simultaneously in the surroundings of Budapest (Góczán, Marosi, Pécsi, Szilárd, Somogyi), in the area of the Mezőföld (Ádám, Marosi, Szilárd) and in the Hungarian section of the Danube Valley (Pécsi) as well as in the Danube—Tisza Mid-Region (Pécsi, Szilárd). Later the development of the Little Plain (Góczán, Pécsi, Somogyi), of the gravel sheet beyond the Rába River (Ádám), of the Somogy—Tolna Hill Region (Ádám, Marosi, Szilárd) and of the region of Lake Balaton (Góczán, Marosi, Szilárd) was studied.

a) *Development of the Buda Mountains and of the Pest Plain*

The GRI has set itself, above all, the task of examining the physical geography of Budapest. The outstanding representatives of the disciplines related to geography have also been drawn into this work. This has resulted in the publication of the monograph *Physical Aspect of Budapest* compiled under the direction of the GRI. It comprises the synthesis of the geology (F. Horvitzky, F. Szentes, L. Szöcs, Z. Schréter), the geomorphology (L. Góczán, S. Láng, J. Szilárd, Pécsi, Marosi), the climatology (N. Baesó), the hydrography and hydrology (W. Lászlóffy, L. Góczán, S. Somogyi), as well as of the biogeography (B. Zólyomi) and soil geography (Z. Fekete) of Budapest and its immediate surroundings by outstanding specialists. The book is not a purely geographical work, but an excellent synthesis of the ecological conditions of Budapest.

Encouraged by this work, the GRI has endeavoured to publish a physiographic synthesis of the most recent scientific results obtained in the field of the physiography and of the related sciences. The result is a book, *The Physical Geography of Budapest*, based on a broad literature and on our more recent researches, describing the complex history of the formation of the Buda Mountains and the Pest Plain (Pécsi 1959c).

The geographic structure of the landscape, the surface relief of the Budapest area have a two-fold aspect: the very intensively articulated Buda Mountains on the right bank of the Danube, and one section of the terraced Danube Valley, the so-called Pest Plain, on the left bank.

The Buda Mountains are peneplaned block mountains of medium height (350 to 550 m a. s. l.) arranged in mosaical juxtaposition, made up mainly of a series of Mesozoic horsts and dissected by small basins and by faulted valleys exhibiting solid outlines.

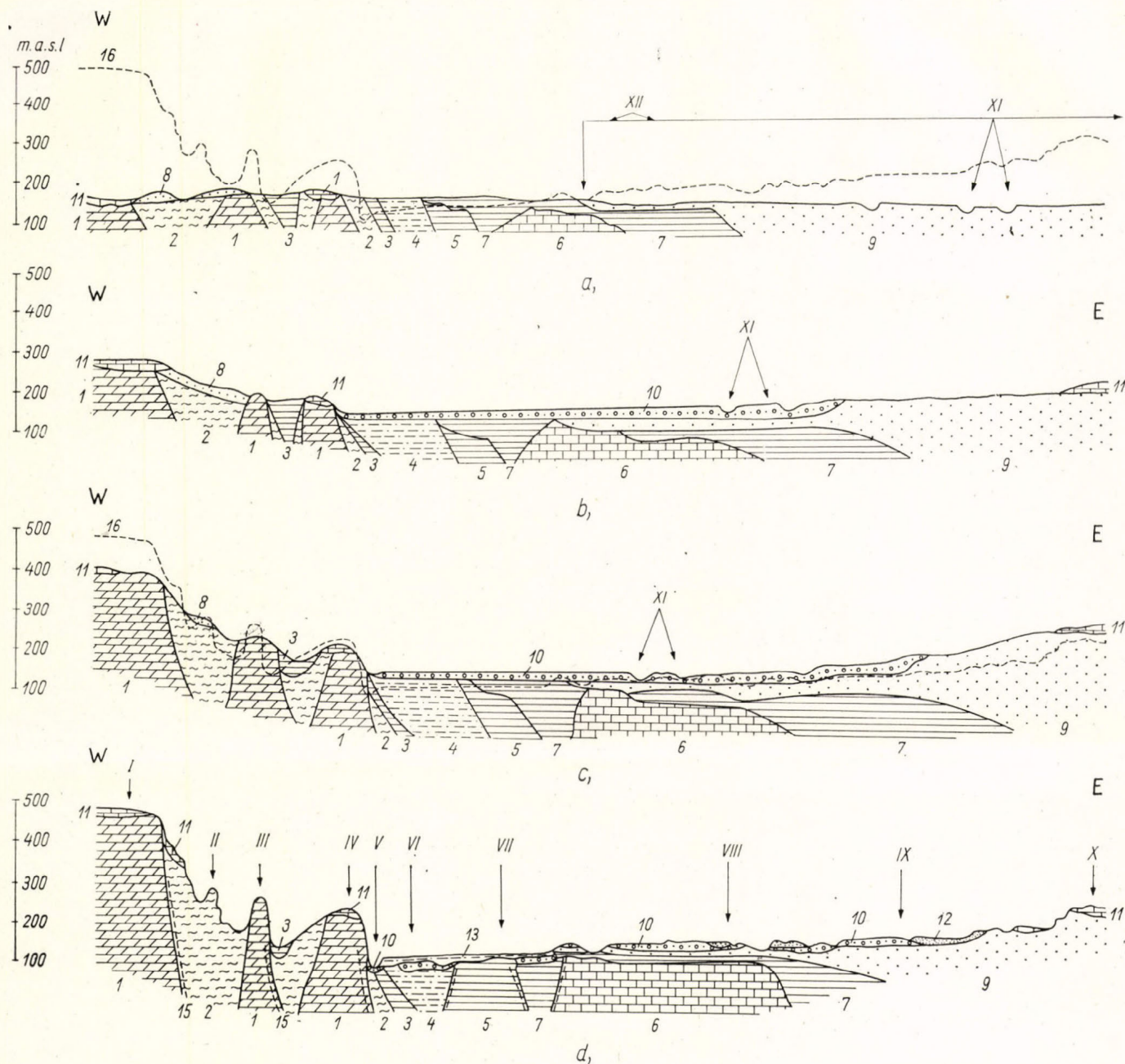


Fig. 73. Morphogenesis of the Pest Plain section of the Danube Valley since upper Pliocene

a — morphological and geological view in upper Pliocene (Astian stage), *b* — at the beginning of Pleistocene (Günz Glaciation), *c* — cross-section in the earlier Pleistocene (Mindel glaciation), *d* — present day geomorphological and geological conditions;

I — Széchenyi Hill, II — Márton Hill, III — Sas Hill, IV — Gellért Hill, V — Danube, VI — Nagykörrút, Mező Imre street, VIII — Rákoshagy railway station, IX — Rákoshagy railway station, X — Erdő Hill, XI — Palaeo-Danube, XII — deposit area of alluvia from the Danube and its tributaries;

1 — dolomite, 2 — Buda marl, 3 — Kiscell clay, 4 — Mediterranean beds, 5 — Sarmatian clays, 6 — Sarmatian limestone, 7 — Pannonian clay, 8 — Pannonian sand, 9 — upper Pliocene sand, 10 — Pleistocene gravel, 11 — travertine, 12 — blown sand, 13 — fluvialite sand and silt, anthropogeneons filling, 15 — fracture fault, 16 — present day surface

The Buda Mountains are the easternmost part of the truncated Mesozoic block mountains of the platform type, crossing in SW—NE direction a considerable part of Transdanubia. The formation of their relief can be traced back to the beginning of the Mesozoic era. The limestones and dolomites making up the base and the bulk of the Buda Mountains were formed during the upper Triassic in a sea of medium depth. In the subsequent periods of the Mesozoic era, most parts of the mountains appear to have already formed a mainland due to an upheaval of the territory. This is proved by the fact that no deposits of Jurassic and Cretaceous seas have been preserved. The fragmentation of the Buda Mountains into blocks began already at the end of the Mesozoic era, i.e. during upper Cretaceous epoch. At the beginning of the Tertiary, during the Eocene, certain portions of the mountains submerged owing to crustal movements.

In the area of the Buda Mountains the Triassic blocks emerged as islands from the Eocene sea, while the area of the Pest Plain remained a coherent mainland during most of the Eocene. The nummulitic limestones and bryozoan marls locally covering the dolomites were deposited in this period. On the other hand, in certain smaller basins there were shallow lagoons offering favourable conditions for coal formation. On the boundary between the Eocene and Oligocene, in consequence of the intensification of crustal movements (Pyrenean movements), the north-western and western parts of the mountains emerged from the sea and pronounced thrust-faulting of the mountains began. An intensive (infra-Oligocene) denudation started on the emerging surface, while along the coast, coarse-grained sandstones and conglomerates, the so-called Hárshegy sandstones, were accumulated. They derived from the crystalline massive which then was still exposed. In the eastern half of the mountains the territory was sinking. The coast line of the sea often changed, and the fragmentation into blocks went on. Since the mid-Oligocene the major part of the Buda Mountains had been emerging, and only the borders of the mountains as well as their faulted valleys and smaller basins were covered by the sea. In these waters the Rupelian (Kiscell) clays were deposited, furnishing raw material for the famous brickworks of Buda since Roman times. On the other hand, the present Pest side of the Danube was then completely flooded by the sea representing the environment of deposition of Kiscell clays.

At the end of the Oligocene the sea withdrew from the region of Budapest, and not only the Buda Mountains, but also the Pest Plain became exundated for a certain length of time.

The ancient Mediterranean Sea which ingressed at the beginning of the Miocene was also confined to the southern foreland of the Buda Mountains and to the outer parts of the Pest Plain. Being connected with the Buda Mountains, the area which serves now as a substrate for the houses of Pest has remained dry.

At that time the Buda Mountains are likely to have been a low hill country, with an undulating tropical peneplain surface. In their surroundings a gradually deepening shallow sea was surging till the end of the Tertiary era.

However, at the end of the Tertiary, in the Pliocene, the Buda Mountains, themselves, began to subside again. Moreover, some of their southern blocks

were inundated for a short time by the Pannonian Sea which covered vast areas on the Pest side of the Danube. This sinking was succeeded, again, by an uplift throughout the region of Budapest so that the Pannonian Sea covering the Hungarian Basin withdrew definitively from the territory of Hungary. Nevertheless, the travertine mantle, dating from the end of the Pliocene to the beginning of the Pleistocene, which covers the eastern and southern borders of the Buda Mountains, testifies that much of the area represented, even that time, a surface lying much lower than its environment. In fact, the travertine was deposited at low levels, upon plane, lakey-marshy surfaces lying close to the local base level of erosion. The 480 m high dolomite block, mantled by recent travertine, of the present Szabadság Hill did not exist during the formation of the travertine mantle (on the Pliocene-Pleistocene boundary). It rose to mountain heights as a result of the intensive uplifting effect of the crustal movements which started at the very end of the Pliocene epoch and lasted till the beginning of the Quaternary period. The Danube also appeared at this time on the eastern border of the Buda Mountains which may have represented a hill landscape with a relative height of 50 to 100 m as compared to the contemporaneous valley of the Danube, while at present time the differences in level attain 300 to 450 m (Fig. 73).

Consequently, the relief of the Buda Mountains assumed its present shape under the influence of quite recent uplifts beginning during the Quaternary. The erosive processes scoured out smaller valleys and ravines in the mountain body. On the other hand, young pediments, talus slopes and cryoplanation terraces formed all round the mountains under semiarid, cold-dry climates of a periglacial type (Fig. 59). The slope loesses and the other slope deposits mantled the slopes of the mountains, the valleys and the basins at the end of the Pleistocene, so that the barren rocky slopes covered by detritus quasi put on a dress. In the Holocene the loess mantle was intensively dissected by the erosional ravines and gullies, which produced alluvial accretion in the soles of valleys.

After the regression of the Pannonian Sea the area of the Pest Plain was modelled and shaped by the Palaeo-Danube which flowed across the Visegrád Gorge. During the Quaternary era the crustal movements did not cease here either, but while the Buda Mountains were rising, the Pest Plain sank to different degrees. The southern part of the Pest Plain represents the northern border of the large kettle-like Quaternary depression of the central area of the Great Plain. The Danube found its runoff towards this centre of the Great Plain across the rhythmically sinking marginal subsidences. Being a portion of the Danube Valley, the Pest Plain represents a marginal transition between the sinking Great Plain and the uplifting central mountains. At the beginning of the Quaternary era the Danube built up an enormous alluvial fan in which it was cut down repeatedly by the rhythmical sinking of the Great Plain and formed a series of alluvial terraces (for details, see Pécsi 1960*d* and Section 12c). Above the present flood plain, five additional Pleistocene terraces could be detected (Figs 1, 4, 74). In the modelling of the Pest Plain's relief the wind also was a considerable agent, cutting and accumulating blown-sand forms on the surface of the terraces. In addition, in the periglacial an important role was played by frost action. The left tributaries of the Danube scoured

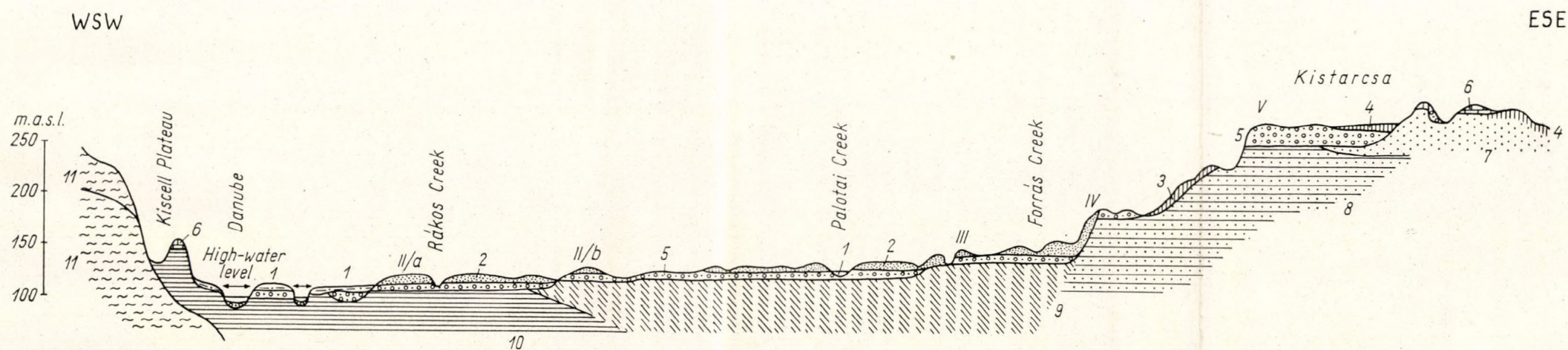


FIG. 74. Cross-section along the Danube Valley between Óbuda and Kerepes

1 — Flood plain silt, 2 — blown sand, 3 — loess with slope debris, 4 — loess, 5 — terrace gravel and sand, (I—V), 6 — travertine, 7 — upper Pliocene fluvialite sand, 8 — Pannonian clay and sand, 9 — Mediterranean beds, 10 — Kiscell clay (Oligocene), 11 — Bryozoan and Buda marl

out broad valleys in the surfaces of the higher terraces. The direction of their flow is very distinctive because at their mouth they flow in a direction which is inverse to that of their drainage. The direction of their flow and of their valleys, as well as certain reaches of the Danube, have been defined by the tectonic lines still active to-day.

b) *Development of the Hungarian Section of the Danube Valley*

The age determinations concerning the formation of the terraces and the horizons of the Danube have been accomplished by M. Pécsi (1956c, 1959a).

(i) FLOOD PLAIN HORIZONS

From the position of the higher and the lower flood plain levels (terrace I) Pécsi has inferred that the Danube has always had — as also in modern times — a lower and a higher flood plain horizon. The difference in height between them is due to the differential modelling effect of the extreme values of the water regime. Forms of transition may also exist between the two extreme values, i.e. the difference of age between the formation of the higher and lower flood plains is not always a proper age difference. In the Great and the Little Plains both horizons may date even from the late Holocene. In the reaches of the Danube corresponding to the central mountains, the body of the higher horizon of the flood plain is largely covered by early Holocene Danube deposits, and the late Holocene silt cover appears to be dry thin. In the subsiding lowland reaches of the Danube the higher horizon of the flood plain is built up by alluvial fan-like forms. That is why flood plain horizons of equal altitude may consist either of late or of early Holocene sediments. However, even Pleistocene sediments may lie within the flood plain horizon, as in the case of the edges of the recent alluvial plains (Fig. 42).

(ii) TERRACES*

The accretion of terrace II by gravels can be related to the end of the late Pleistocene. Its incision took place during postglacial times, this terrace is generally covered by blown sand but never by typical loess. Its characteristic fauna is *Elephas primigenius*. In the upper part of the gravel terrace the remnants of cryoturbation forms due to periglacial soil frost can be seen.

The accretion of terrace II/b by gravels may date from the end of the late Pleistocene (from that of the Würm in terms of the nomenclature adopted in Hungary, and from the late Riss according to Büdel's Pleistocene chronology). The material of the terrace is covered in many places by thick loess or sandy loess. Its vertebrate fauna is characterized by the ancient form of *Elephas primigenius*. In the upper horizon of the terrace material the rem-

* The river terraces from the flood plain horizons towards the older and higher terraces have been marked with Roman numerals during the last three decades in the Hungarian literature on terrace morphology. This mode of marking has been generally adopted so that any change in it would cause trouble. Therefore, even though not considering the flood plain horizon I to be a real terrace, the author still applies the old denomination (see Table I).

nants of the cryoturbation features reflecting the effect of the glacial soil frost are frequent. These features are much larger and more complex than the similar phenomena of the former terrace. There appear two subsequent generations of frost phenomena (Fig. 43).

The correlation of the formation of terraces permits us to relate the accretion of terrace III by gravels to the middle Pleistocene. In some cases the terrace could be proved to date from the middle Pleistocene, and probably from the Riss glaciation (findings of *Elephas antiquus*).

The filling of terrace IV with gravel can be related to the early Pleistocene (Mindel glaciation). Its vertebrate fauna has been assigned to the horizon of *Elephas trogontherii*. The date from the region of Budapest suggest that the downcutting of this terrace began under the influence of the intensive crustal movements that had started at the end of the Mindel glaciation.

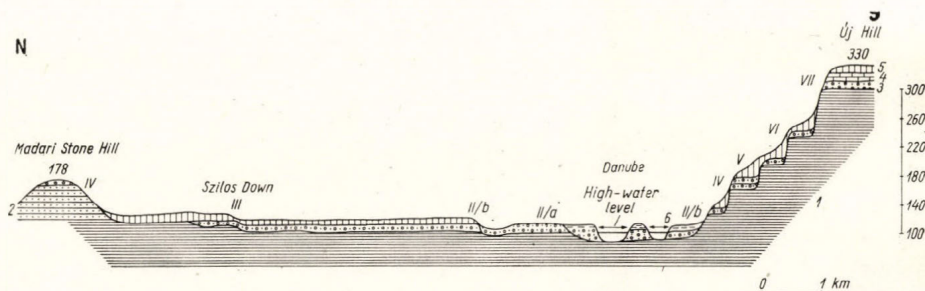


FIG. 75. Cross-section between Dunaszentmiklós and Madar

1 — Pannonian clay, 2 — Pannonian clayey sand, sandy clay, 3 — terrace gravel and sand of different age (terrace I—VII), 4 — travertine, 5 — loess, 6 — silt

On the basis of the morphological and stratigraphical position of terrace V, we can date its formation from the early Pleistocene. It is younger than the extensive, high-seated travertine mantle known from the region of Budapest and from the northern border of the Gerecse Mountains. The remnants of *Mammot (Mastodon) borsoni* occurring in it were recently (1953) related by Kretzói to the Günz glaciation. The gravels are dissected in the gravel quarry situated on the Sas Hill at Pestlőrinc by two cryoturbation horizons characterized by frost sacs and ice wedges (Fig. 45).

In the mountainous sections of the Danube, at least two terraces (V and VI) correspond to the huge alluvial fan of the Budapest district (terrace V). On the northern border of the Gerecse Mountains and in the Visegrád Gorge, terrace VI was also filled with gravel at the beginning of the Pleistocene (Figs 74—76).

Terrace VII known from the mountainous reaches of the Danube is upper Pliocene in age; south of Dunaalmás—Neszmély, it underlies travertines dating from the Günz glaciation. Nevertheless, it is quite possible that the terraces made up of coarse-grained gravelly deposits all belong to the Pleistocene. The Pleistocene was namely the starting point of a phase in fluvial erosion which produced immense quantities of coarse-grained sediments, in contrast to the deposits of previous periods.

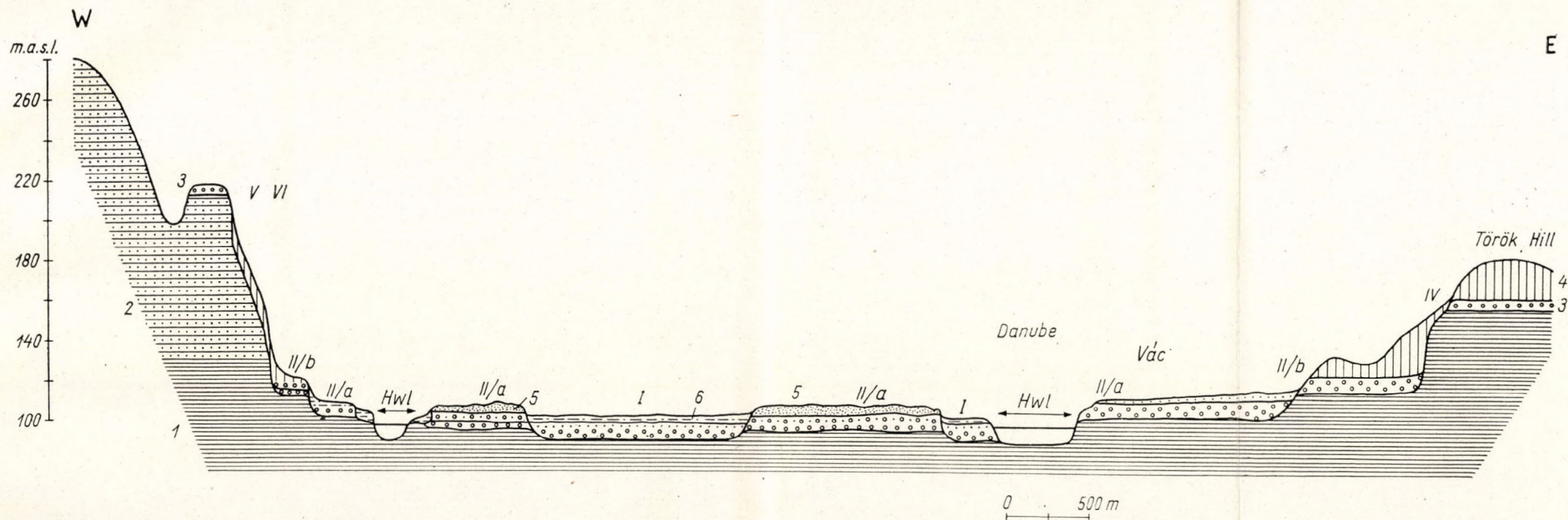


Fig. 76. Cross-section of the Danube Bend from Vác to Tahi

1 — Oligocene clay, 2 — Oligocene sandy clay, 3 — flood plains of different height and terrace dating: I from the Holocene, II/a from the end of Würm, II/b from the beginning of Würm, IV from Mindel, V or VI from Günz — pre-Günz glacial; 4 — loess with one or two fossil loam zones, 5 — blown sand, 6 — sandy flood plain silt; Hwl — high water level

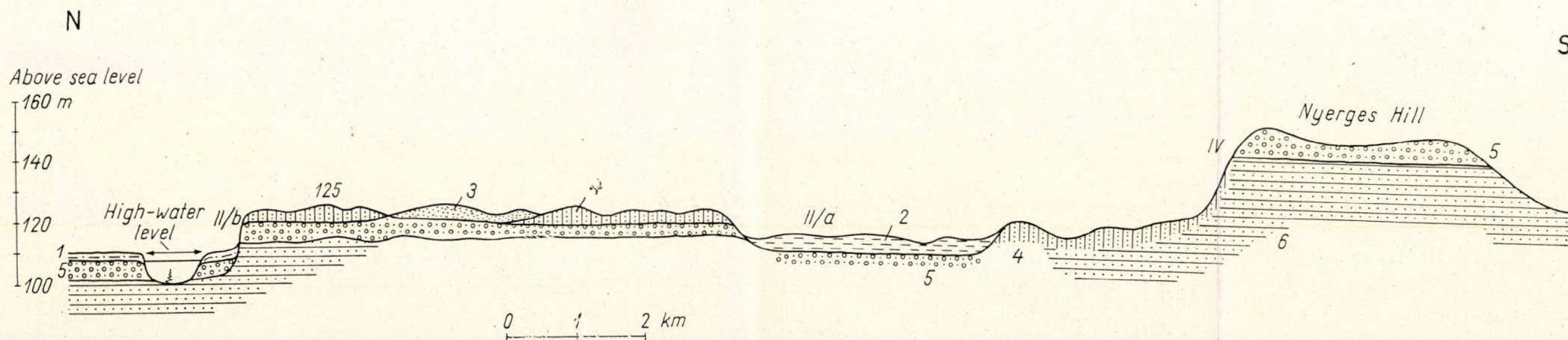


Fig. 77. The location of the Danube terraces on the margins of the Little Plain

1 — Fluvial mud, 2 — loess mud, 3 — Windblown sand, 4 — loess sand, 5 — terrace gravel and sand 6 — Pannonian clay and sand

The thick, cross-bedded sands on the border of the Little Plain and in the region of Gödöllő—Isaszeg are certainly upper Pliocene (Astian substage). They can be conceived as a deltaic formation of the Palaeo-Danube and of its tributaries which came into being on the northern margin of the inner lake system still existing in the Great Plain during the upper Pleistocene.

(iii) INTENSITY OF THE PLEISTOCENE CRUSTAL MOVEMENTS AS SUGGESTED
BY THE DISLOCATIONS OF THE DANUBE TERRACES

In the further discussion we shall refer to the longitudinal section showing the patterns of the Danube terraces in which a short summary of our terrace-morphological investigations carried out so far is presented (Fig. 1). The intensity and the age of the tectonic movements that subsequently raised or lowered the synchronous terraces to different levels can also be inferred from the patterns of the terraces. For instance, we can prove that the differences in level caused by tectonic movement since late Pleistocene times appear to amount to about 10 to 20 m as a whole. These figures vary locally and comprise several stages. The results of the terrace-morphological investigations permit us to estimate even the intensity of the crustal movements that took place during the whole Pleistocene in some well known reaches of the Danube Valley. For instance, in the region of Budapest, between Mogyoród and Vecsés, differences in level of about 130—150 m can be measured on the surface of the early Pleistocene terrace V (Fig. 1). Moreover, in the section between the Visegrád Gorge and the southern part of Budapest, we may reckon with even greater relative movements ranging from 200 to 250 m for the same terrace.

If the dislocations of different amplitudes which set in after the formation of the terraces in the individual sections are not considered or detected, the synchronous terraces cannot be exactly identified and correlated. It follows that the correlation of the higher terraces, in which commonly there is no fauna of stratigraphic value available, cannot be accomplished merely on the basis of the data of their relative altitude.

The exact knowledge of the amplitudes of posterior terrace dislocations in a given valley section, the lithological analysis of the rocks making up the terraces, the degree of roundness of the gravels, the stratigraphic position of the terrace material as well as the relative height of the terraces within certain valley profiles have provided information and evidence for the correlation of the terraces of the Danube over reaches though of different length but of roughly the same geological structure.

iv) POSSIBILITY OF THE SYNCHRONOUS FORMATION OF DANUBE TERRACE SYSTEMS

The strictly synchronous filling (e.g. within one glacial phase) with gravels and the downcutting of certain terraces of the Danube over its longer reaches, i.e. the synchronous formation of the terraces is still very controversial. Many examples testify that, even in the case of the Hungarian reaches of the Danube, we cannot insist on a strict synchronism in the formation of the individual terrace horizons because of the prevailing diversity of the local

conditions. Pécsi became even more convinced of the rightness of the above statement while correlating the terraces of the Hungarian, Austrian and Rumanian sections of the Danube. For example, during the formation of the older alluvial fan of the Little Plain, i.e. while the terrace formation was interrupted until the major interglacial period, three Danube terraces (those of Laaerberg, Wienerberg and Arsenal) formed in the region of Vienna. In the centre of the Little Plain, in the Moson Depression, the rhythmical subsidence proceeding since the beginning of the major interglacial period resulted in the formation of a younger alluvial fan and no terraces were formed, while in the region of Vienna and in the eastern half of the Little Plain (Fig. 77) four younger terraces were scoured out (Pécsi 1957b, 1959a).

(v) MECHANISM OF THE FORMATION OF THE DANUBE TERRACES

The formation of the terraces of the Danube cannot be explained simply by the climatic theory of terraces; Pécsi's observations suggest that the formation of the Danube terraces was a result of the aggregate effect of the crustal movements and of climatic changes. As far as the mountainous reaches of the Danube are concerned, the role of the crustal movements should be emphasized, first of all, as their effect seems to have been decisive. The important function of the crustal movements in the formation of the terraced Danube Valley is sufficiently proved by the fact that in the Little and the Great Plains the older Danube deposits lie at depths of several hundred metres. However in the central mountainous reaches of the Danube, the gravels which may be firmly held for Danube terraces are encountered even higher than 200 m above the Danube level. The formation of the reaches of the Danube Valley section, such as the 150 to 200 m deep valley with 7 to 8 terraces of the reaches between Dunaalmás and Vác, cannot be interpreted simply by the climatic theory of terraces (Figs 2, 3).

If the effect of crustal movements is disregarded the formation of such valley sections are unexplicable not only because even the horizons belonging to the same terrace system have shifted to different relative heights, but also because the rhythmical climatic changes would not be able to produce deep valleys unless rising movements were involved.

Nevertheless, the climatic effect has had an important part in the filling of the terraces with gravels: the unrounded boulders reaching to 0.3 to 1.0 m in diameter testify that the time of the filling with gravels coincides with the glaciations, for it is obvious that these unrounded blocks could be inserted among the smaller rounded gravels only if embedded in ice.

Pécsi's observations suggest that the filling with gravels coincided in a number of terraces with the first half of the glaciations, and that the more vigorous crustal movements can be assigned to the beginning of the interglacials, in certain cases to the end of the glaciation (e.g. Mindel).

Relying on the results of earlier investigations (Schafarzik 1918, Kéz 1933a, b, 1939, Szádeczky-Kardoss 1938, Bulla 1936, 1939, 1941, Sümeghy 1939, 1948, 1953) and his own studies of ten years, Pécsi briefly summarized the history of development of the Hungarian reaches of the Danube

The Palaeo-Danube made its appearance in our country after the retreat of the Pannonian Sea, i.e. at the beginning of the upper Pliocene. Initially, it may have followed a southern trend shown by E. Szádeczky-Kardoss flowing across the fluvio-lacustrine drainage system in the southern part of the Little Plain, roughly along the present valley of the Dráva towards the Dráva Depression. At that time it terminated probably in the inner lake system of the southern part of the Great Plain. This inner lake system was probably connected through the Iron Gates to the Levantine inner lake system of the Rumanian Plain.

The Palaeo-Danube found its path through the Visegrád Gorge towards the Great Plain in the second half of the upper Pliocene. It joined the inner lake system of the central part of the Great Plain in the region of the Buda Mountains and filled the depressions of the Great Plain with sediment by flowing across the Buda Mountains. The communication through the Iron Gates eastwards persisted further on. By the end of the upper Pliocene the orographic patterns differed considerably from the present orography. The volcanic mountains between Esztergom and Visegrád and the southern part of the Börzsöny as well as the Buda Mountains (i.e. the Hungarian Central Mountains in general) were substantially lower than today, i.e. our Central Mountains did not form such a sharp orographic boundary between the Little and the Great Plains as they do nowadays. Since the upper Pliocene times the region of the actual Visegrád Gorge has risen to form medium-high mountains. The declination of the Danube towards the Visegrád Mountains — as inferred from several partial data — is very likely to have been directed by crustal movements. This is suggested mainly by the fact that in the Visegrád Gorge the Leithakalk cover was dislocated to very different levels in the Pliocene. The Palaeo-Danube may thus have formed a nearly normal gradient curve between the Little and the Great Plains.

This direction of flow between the two Plains was not durably changed essentially by the intensive crustal movements starting at the Pliocene-Pleistocene boundary; either. Moreover, during the Pleistocene, the gradual intensive sinking of the Great Plain in the eastern foreland of the Buda Mountains forced the river to cut down and to scour out a deep, terraced valley in its central mountain reaches. The Danube had developed the Visegrád Gorge in an intercolline depression which gradually rose during the Pleistocene so that also an antecedent valley formation set in.

B. Bulla suggests also the possibility of valley formation by capture, and L. Kádár that of regressive valley formation (Marosi 1959).

In the Pleistocene the Danube crossed the Great Plain in SE direction, building in its way a huge alluvial fan and flowing towards the large central depression of the Great Plain which was situated in the Trans-Tisza Region. Following the changes of the younger marginal troughs, it shifted over its alluvial fan more and more to the west. In the middle Pleistocene its course was probably directed SSW across the area between the present Danube and Tisza Rivers. Its western boundary ran along the edge of the Mezőföld platform which was then situated 25 to 30 km further east and was lower than

it is now. Its present general N—S direction of flow along the western border of the Great Plain was assumed in the late Pleistocene likewise under the influence of a recent depression. Since the second half of the late Pleistocene it has been building its alluvial fan, at high floods, between Budapest and Baja in a long, 20 to 30 m wide belt.

c) Morphogenetic Problems of the Danube—Tisza Mid-Region

The most vexing questions are and have always been the extension of the alluvium of the Danube in the area between the two rivers; the time when the Danube occupied its present valley running N—S; whether it flowed during the Pleistocene in SE direction diagonally across the area, and if so, exactly when? From a practical point of view it is also important to know how thick is the fluvial filling and how much the Quaternary crustal movements are responsible for the deposition of alluvium and for the development of forms.

The answers to these questions have been very different according to the current stage of the application of scientific research methods.

Having taken into consideration the results obtained earlier and the conclusions drawn from lengthy discussions, M. Pécsi re-weighed these results on the basis of his own observations. For this purpose, he studied the stratigraphic columns of most artesian wells and prospecting boreholes, and performed numerous measurements in mineralogy and petrography, on heavy minerals and on the roundness of alluvial gravels and pebbles.

The application of these methods permitted us to enhance the effectiveness of the geographical investigations and to provide a more exact basis for geographical judgement.

The deposits of the lowland alluvial fan of the Danube and its features which have been preserved up to date could be disclosed in a most consistent and most demonstrative way between Vác and Budapest (Fig. 4).

In the upper Pliocene, when the Danube and the Inner Carpathian rivers began to issue from the mountains upon the Great Plain, they were accumulating, for a very long time, enormous amounts of coarse sands in these reaches, along the line of Gödöllő—Isaszeg. After the regression of the Pannonian Sea these cross-bedded (Astian) sands were deposited and formed a delta on the border of the remanent shallow inner lake system. Owing to its accretion, the inner lake gradually shrank so that the deposition of sands expanded towards the centre of the Great Plain, too.

The initial phase of the Pleistocene period during which well discernable intensive crustal movements and the above-mentioned process of sedimentation had taken place, was succeeded by a period of large-scale erosion. The sands which had been accumulated within the range of the afore-mentioned reaches of the Danube were deeply eroded throughout the area of the Pest Plain. The Danube built an enormous gravelly alluvial fan for a long time, up to and during the Günz glaciation (terrace V). In the Pest Plain this gravelly alluvial fan is found on the surface at heights of 130 to 250 m, while in the region of Nagykőrös—Kecskemét it has been encountered in boreholes at

depths of 250 to 300 m. This means that it has gradually sunk with the sinking of the Great Plain.

In the Pest Plain, besides the alluvial terrace, four additional lower terraces can be detected: II/a, II/b (Würm glacial terraces), III (Riss), IV (Mindel glacial terrace). The three older terraces issue SE in the southern part of the Pest Plain. Along the lowest one, i.e. terrace II/a, continues S. It can be inferred therefrom that the Danube flowed in the direction corresponding to its present course, i.e. from the north to the south, only during the deposition of the material of this latter terrace.

On the southern margin of the Pest Plain the four terraces of the Danube (terraces II/b, III, IV, V) discontinue on the surface, and the river alluvium continues SE more and more deeply under the surface in the direction of Kecskemét—Kiskunfélegyháza and, what is more, in normal stratigraphic succession with the oldest terrace at the base overlain successively by the younger ones.

The sediments on the ridge of the Danube—Tisza Mid-Region are not primary deposits of the Danube, but mainly blown sands with subordinate loesses. However, the blown sands have been redeposited from the alluvium of the Danube. In fact, the Danube flowed in its present north-south valley at least during the last glaciation and ever since. Accordingly, in the Würm glaciation and the Holocene, eolian deposits have formed in the Danube—Tisza Mid-Region. The thicknesses of these deposits may exceed even 20—40—60 m, for in the present valley of the Danube the thickness of the synchronous river sediments also reaches 20—40—60 m. According to this, when considering the analyses of the sediments, the narrow troughs — pans — with solid outlines running SE in the area in question cannot be held as former channels of the Danube (Miháلتz 1950, 1953, Láng 1960, Pécsi 1959a, 1960b) as it was believed earlier by several authors. The fluvial sediments of the Danube are encountered much deeper. In addition, these valleys running SE are so narrow (20 to 200 m) that they cannot be conceived as Danube channels, a considerable part of the sands present in them being blown sands. The blown sands are overlain by calcareous silts or by meadow clays and meadow limestones. This fact also suggests that they have been deposited from slowly flowing and intermittently stagnating waters directed from the watershed of the area in question towards the Tisza, or NW towards the Danube. Their formation started during the Pleistocene, since also the earlier Pleistocene troughs have been locally buried with loess. The loess blankets adjust themselves to the undulation of the relief. On the other hand, in the surroundings of Kecskemét—Lajosmizse, natron lakes are arranged parallel to one another in NW—SE direction in such depressions filled with loess.

It could not yet be definitely established what surface-shaping forces were more active in the formation of these small troughs running consistently NW—SE in which these minor, slow water streams often occur. We are not yet sure whether the wind or the fluvial erosion or both have acted along the tectonic lines. We must probably reckon with the combined modelling effect of several agents.

On the surface of the ridge the following blown-sand features create larger form groups: wind-blown furrows, mounds, longitudinal end dunes, and residual

ridges. They form, all together, several peculiar dune areas (Bikatorok, Ágasegyháza, Bócsa, Tázlár, Illancs, Pusztamérgecs).

Most of these forms date from the Holocene. This is proved, for instance, by the fact that the sand dune cover of Illancs rests on loesses. In these dune regions even the traces of the original plant communities of the Hungarian steppe type — poplars-junipers, sand steppe meadow — have been preserved.

Between the areas covered with blown-sand dunes there are wide-spread, dammed, waterlogged oval pans directed from the north to the south as well as flat, trough-shaped, ill-drained basins. Their formation may be related

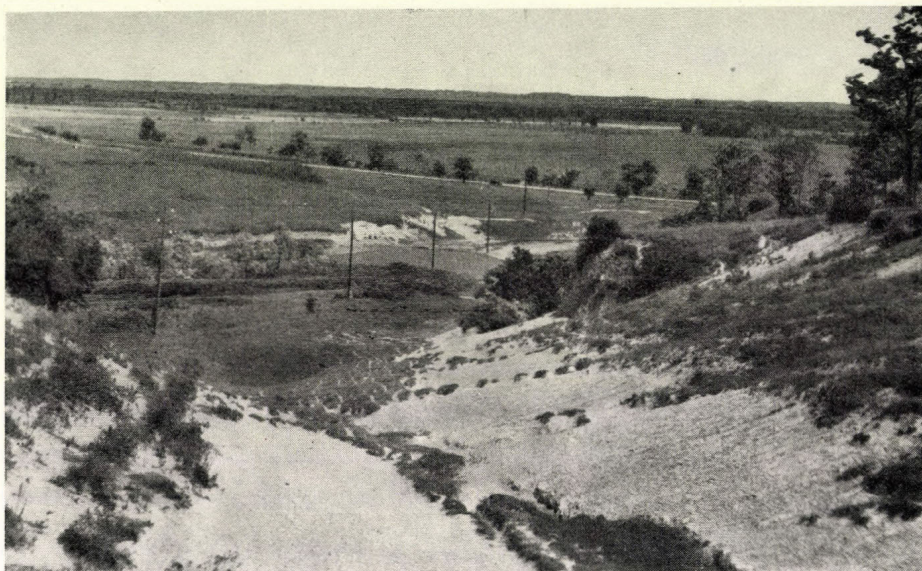


FIG. 78. The wide alluvial flood plain of the Danube Valley as seen from Paks (Photo E. Vajda)

to damming by blown sands. Most of them have already been drained, but some relics of the boggy plant communities have survived (Lake Kolom, Lake Izsák, Meadow of Ágasegyháza).

The strata exposed in boreholes testify that the southernmost part of the ridge, i.e. the Hungarian sector of the Bácska Loess Platform, did not sink considerably during the Pleistocene. It was probably an area situated outside the territory of accumulation of the alluvium of the Danube which ran SE in the Danube—Tisza Mid-Region. Before the formation of the loess cover only the tributaries issuing from Transdanubia may have run across this area.

In the 20 to 30 km wide Danube Valley, running N—S (Fig. 78) the landscape forms are the results of the erosive and accumulating activity of the Danube, unlike those of the ridge. Although besides the erosional monadnocks (Solti Hill, Tétel Hill) there are eolian mounds and river bank dunes

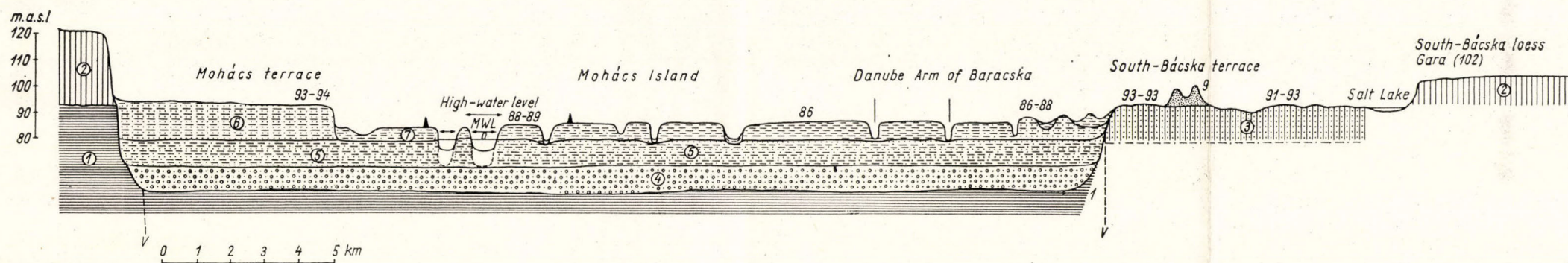


FIG. 79. Danube terrace in the Great Plain

1 — Pannonian clay and sandy clay, 2 — loess, 3 — sandy loess, with loess-like sandy mud in the upper zones, 4 — terrace gravel and sand, 5 — fluvatile sandy mud, 6 — loess-like sand and gravel, 7 — sandy flood-plain mud, 8 — flood plain mud, 9 — wind-blown sand

too, but the most frequent landscape forms are the remnants mostly filled up of the former dead channels and oxbows (Fig. 79).

In the course of the physiographical investigations in the Danube—Tisza Mid-Region the analysis of the drilling data, profiles and sediments has per-

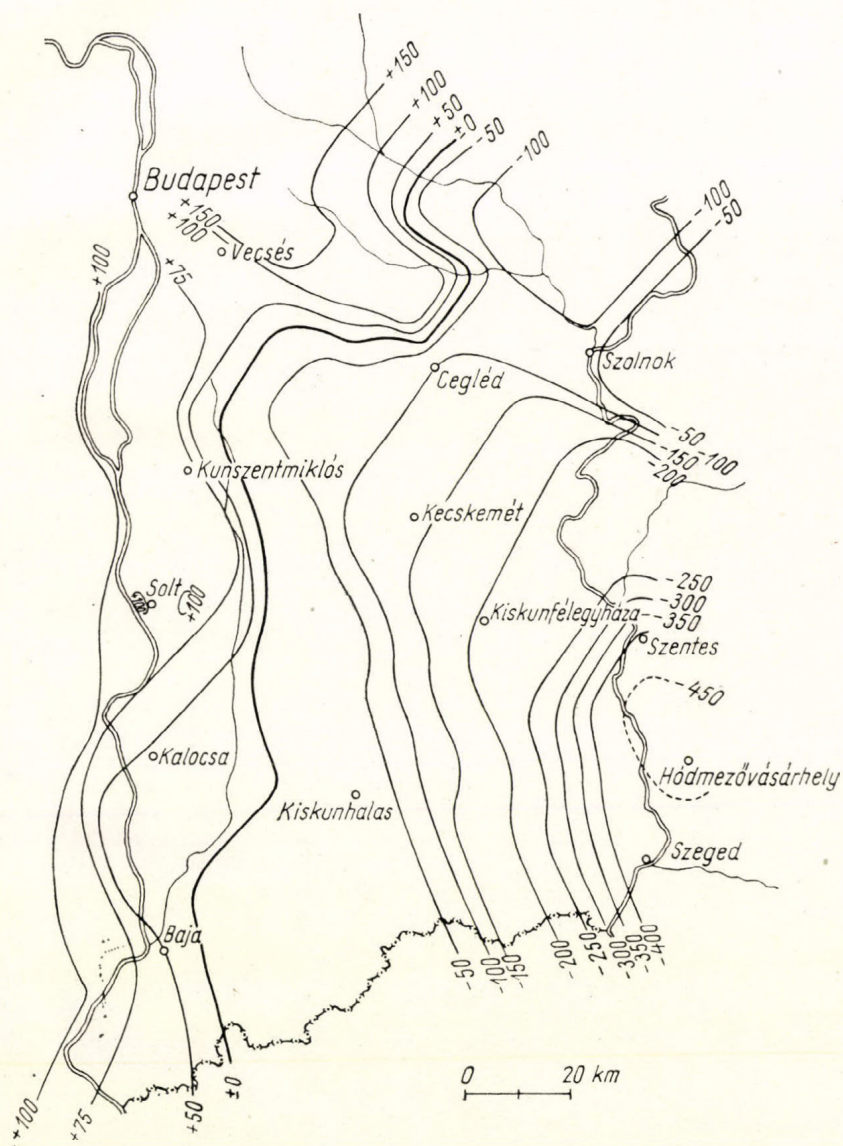


FIG. 80. Substratum of the Pleistocene beds in the Danube—Tisza Mid-Region related to the sea level. According to I. Urbancsek. The area lies 100 to 200 m a. s. l.

mitted us to state that the thickness of the sediments deposited during the Pleistocene as well as after the Pannonian epoch is substantially greater than it was earlier believed to be. The position of the Pleistocene beds in relation to the sea level is well illustrated by Fig. 80, showing that the Pleistocene series is 10 to 20 m thick in the region of Budapest, 250 to 300 m thick between Kecskemét and Kiskunfélegyháza, and 400 to 500 m thick between Szentes and Szeged.

The largest average thickness of the Pleistocene beds measuring 300 to 600 m and the position of their basement related to the sea level witness that the Great Plain sank considerably in the Pleistocene. But when considering the thickness of the post-Pannonian deposits, exceeding even 1000 m, the magnitude of the post-Pannonian depression of the Great Plain becomes even more obvious, partly confirming the suggestion that the Great Plain was the largest local base level of the Carpathian Basin in the upper Pliocene and the Pleistocene. Owing to the uplift of the whole Carpathian mountain frame, the Upper Pannonian Sea completely withdrew from the Great Plain. At this time — in the upper Pliocene — the surface of the Great Plain rose slightly above the sea level. However, at present these sediments dating from the end of the upper Pannonian lie deeper than 1000 m below the sea level, as for instance in the borehole sunk at Hódmezővásárhely. This situation can only be conceived if the mountain frame has constantly risen, while the basin has slowly been sinking and the subsidence has been filled with the deposits of the rivers. Otherwise, the Pannonian inner lake would not have retired from the Great Plain.

d) *The Geomorphological Evolution of the Mezőföld*

The students of this region (Ádám, Marosi, Szilárd 1959) have traced in detail the geomorphological development of the Mezőföld area since the setting in of continental conditions in connection with the gradual regression of the Upper Pannonian inner lake. Towards the end of the Pliocene the disintegrated Upper Pannonian inner lake rapidly freshened, shrank and was accreted. These processes were connected with the rhythmical upheaval of the whole Pannonian Basin. By the end of the Pliocene the territory of the Mezőföld was completely exundated, and the water of the inner lake was left over only in smaller, closed marshy depressions. Over the slightly rising Mezőföld Platform denudation began as early as the upper Pliocene (Levantine stage) so that the Levantine sediments known from Southern Slavonia were not deposited here. In the upper Pliocene the surface of the Mezőföld was most vigorously denuded by fluvial erosion, the base level of which was represented by the relatively sinking territory of the adjacent Great Plain and by the southern part of the Mezőföld. In this period some 150 to 200 m thick, loose Pannonian rock suit was removed from the northern area of the Mezőföld. The students of this region attribute, besides the considerable and prolonged upper Pliocene erosive action, an important role to the crustal movements in the modelling of the Mezőföld. They have revealed frequent unilateral prominences and subsidences caused by vertical movements. The tectonic lines trending NW—SE and those normal to them have had the



FIG. 81. Landscape detail of the erosion-derasion hill region of Mezőföld. (Photo E. Vajda.)



FIG. 82. Detail from the slightly undulating loess plateau of Mezőföld (Photo E. Vajda.)

greatest importance in the formation of the tectonic features of the area (Fig. 68). The crustal movements that took place on the boundary between the Upper Pliocene and the Pleistocene led to unequal upheaval or subsidence. In the northern area being in contact with the Central Mountains, the rising movements prevailed, while in the southern area of the Mezőföld a considerable subsidence took place. Ádám suggests that the NW—SE faults disturbing the Pannonian beds of the Mezőföld have revived along the tectonic lines of the basement underlying gradually the thick Pannonian deposits, that is the tectonic structure of the ancient basement was rejuvenated. These

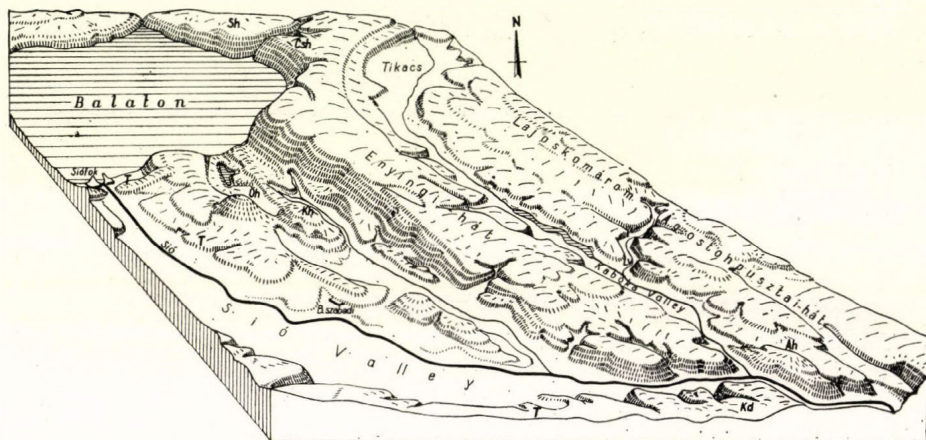


FIG. 83. Block diagram of the Enying Ridge and the Lajoskomárom—Ágostonpuszta ridge (According to I. Szilárd.)

Csh — Csittény Hill, *Sh* — Sér Hill, *Kh* — Külső Hill, *Oh* — Öreg Hill, *Kd* — Kavicsos Hillock, *Ah* — Arany Hill, *Lv* — Les Valley, *T* — terrace cut in a Pleistocene barrier beach

tectonic lines trending NW—SE have played an important role even in modelling the present landscape and in offering the paths for the present river drainage.

The denudation of the Pannonian beds of the Mezőföld continued during the Pleistocene. Although the erosive action was gradually losing its intensity as the accretion of the Great Plain advanced, the larger part of the Mezőföld remained the field of the activity of fluvial erosion and accumulation till the beginning of the late Pleistocene. The wide gravelly channels and the extensive alluvial fans fed from the direction of the Transdanubian Central Mountains were formed in the early and the middle Pleistocene. Thanks to the above-mentioned processes, the northern, and north-western parts of the Mezőföld were transformed to an erosional rolling landscape with a vivid relief by the middle Pleistocene (Figs 81—84). The loose sediments removed from the eroded rolling landscape and the Central Mountains built vast alluvial fans which were accumulated in the western, eastern and southern parts of the Mezőföld, chiefly simultaneously in the early and middle Pleistocene

by several streams altogether independent of one another. Moreover, the formation of the alluvial fan of the Palaeo-Sárvíz extended even over the late Pleistocene.

While in the afore-mentioned areas it was the activity of fluvial erosion and accumulation that proceeded, in the south-eastern area of the Mezőföld, on the surfaces of the Paks—Pentele platform blocks, the eolian accumulation and loess formation were more pronounced. According to research workers the loess strata in the Mezőföld comprise the complete Pleistocene series of Hungary (cf. Ádám, Marosi, Szilárd 1959).

During the last glaciation the loess formation became predominant also in those areas of the Mezőföld which had earlier been modelled by fluvial erosion and accumulation. Accordingly, most of the Mezőföld is covered

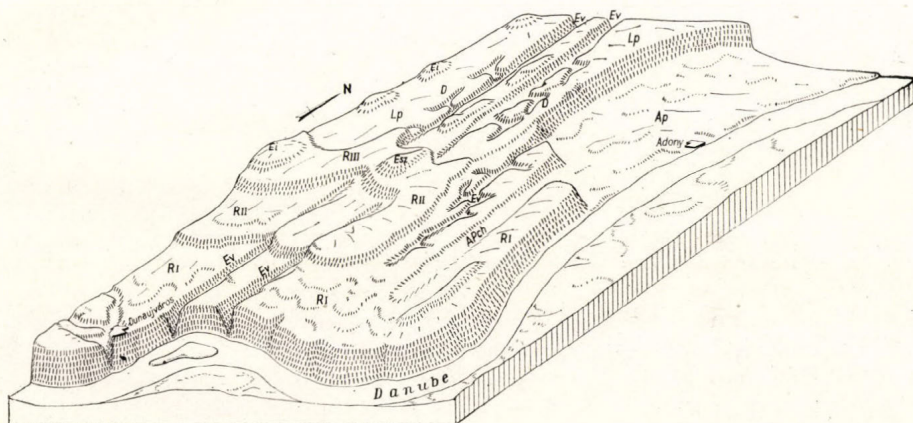


FIG. 84. Block diagram of the northern part of the Pentele loess platform. According to L. Ádám

RI, RII, RIII — Derasion horizons; Ev — erosive valley covered by loess, D — delle, Ei — erosive outlier, L — loess plateau, A Pch — accreted Pleistocene channel, Ap — Adony alluvial plain

only by recent loesses, i.e. by the formations of the last glaciation which, in many places, lie immediately above the denuded Pleistocene beds.

The students of the Mezőföld have also furnished numerous data pointing out the surface-shaping action of the recent crustal movements which took place in the last glaciation. Under the influence of the late Pleistocene sinking movements a number of more or less extensive valley troughs and flat subsidences were born in the area of the Mezőföld. Some of these subsidences continued to sink even during the early Holocene (Zámolyi Basin, Lake Velence, Sárrét etc.). In the early Holocene they developed especially along the Danube. With regard to morphology and geology, the students of the Mezőföld do not consider the Mezőföld as strictly representing a part of the Great Plain, but as an independent geomorphological district differing from the Transdanubian Hill Region as well. Physiographically and especially morphologically, the Mezőföld represents an area of transition linking the Great Plain to the Transdanubian Hill Region.

e) *The Formation of Lake Balaton and of the Transdanubian Hill Region*

(i) SOMOGY HILL REGION

The basement of most of the Somogy Hill Region and of Lake Balaton is formed of variscid crystalline blocks which are overlain by Pannonian clays, sandy clays, sands and by the upper Pliocene cross-bedded sands already mentioned. The latter are in many places more than 1000 m thick. Accordingly, the terrestrial development of the surface began in connection with the formation of the upper Pliocene fluvio-lacustrine system that followed the retreat of the Pannonian Sea. At that time the so-called "Astian" cross-bedded sands of the upper Pliocene accumulated in large amounts. In the eastern part of Outer Somogy these sediments occur only as isolated spots. The withdrawal of the Pannonian Sea from this area was connected also here with the over-all upheaval that started with the Upper Pannonian stage. The tectonic effects of these epeirogenic movements affecting the entire Carpathian Basin can also be demonstrated. Their most conspicuous manifestations are the eruptions of basaltic lavas which began in this epoch in the Balaton Highland. In the territory of the Somogy Hill Region the crustal movements may have provoked small vertical dislocations, too, but in general no morphological changes of a larger scale can be discerned in the deposits of these times. However, the upper Pliocene fluvio-lacustrine sediments locally overlie the marine sediments of the upper Pliocene through unconformity. The volcanic activity and the crustal movements associated with it continued further on. This is shown by the fact that on the southern shore of Lake Balaton, on the Vár Hill of Fonyód, the cross-bedded, fluvio-lacustrine, sandy sediments of the upper Pliocene are overlain by basalt tuffs.

The development of the landscape has been discussed in recent years by S. Marosi, J. Szilárd (1958), S. Marosi (1960, 1962a) and J. Szilárd (1960, 1962) who relied, at the outset, upon the results of the earlier workers (Lóczy 1913, Cholnoky 1918, Szádeczky-Kardoss 1938, Sümeghy 1939, 1951, 1953, 1955, Szabó 1957, Bulla 1943a, Zólyomi 1952). These authors believe that during the upper Pliocene the surface of the Pannonian beds underwent considerable denudation in the territory of the Somogy Hill Region. Assuming the existence of a desert climate at the end of the Pliocene, Lóczy and Cholnoky ascribed these phenomena to deflation, according to the ideas prevailing at that time. Marosi and Szilárd attribute them to fluvial erosion, relying on the relevant investigations of E. Szádeczky-Kardoss, J. Sümeghy, B. Bulla and A. Kéz. In fact, these investigations refute the existence of a desert climate in the Carpathian Basin at the end of the Pliocene as has been suggested by Lóczy and Cholnoky. Nevertheless, Pécsi's researches (1961e) suggest that there are morphological data permitting us to suppose the existence of though not a desert but at least semi-arid climate in the upper Pliocene. This is indicated by the pediments on the mountain border, which intersect the Upper Pannonian beds, too (see Section 5b).

Based on their own investigations, Marosi and Szilárd ascertain that during the upper Pliocene major and minor streams ran across the territories of the Zala Hill Region and of Inner Somogy situated south of the Transdanubian Central Mountains, and also further NE, across the territories of Inner Somogy

and of the Mezőföld, S—SE, i.e. in the direction of the Dráva Depression or the Danube—Tisza Mid-Region. In the area of the Somogy Hill Region, these streams kept on traversing the territory at the beginning of the Quaternary period and even in the Late Pleistocene. Marosi ascribes the gradual uplift of the Central Mountains and of the watershed ridge of Keszthely—Gleichenberg to the beginning of the lower Pleistocene and suggests that along the present Upper Kapos River a depression was formed parallel to Lake Balaton. It stretched from the Zala Hill Region across Inner Somogy (Marosi 1960), Outer Somogy (Szilárd 1960), the southern half of the Hegyhát (Ádám 1960) and the Southern Mezőföld (Marosi 1953) towards

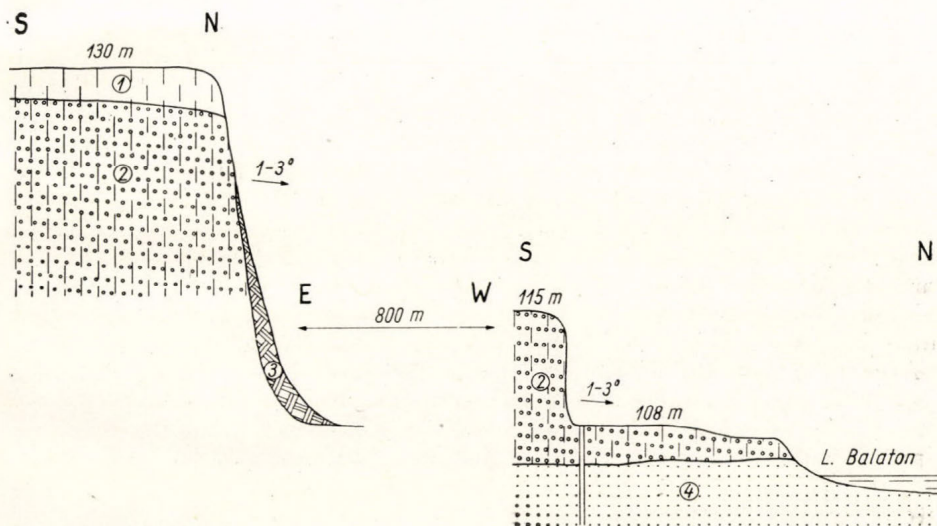


Fig. 85. Cross-section of the high shore at Balatonberény. According to S. Marosi

1 — Loess, 2 — loess with dolomite detritus (0.5 to 3 cm in \varnothing) and fine-grained sediments produced chiefly by solifluction, 3 — slope debris; 4 — Pleistocene fluvialite sands with gravels and with Permian red grits

the Kalocsa Depression. Marosi assumed it to have been an almost continuous fault trough trending WSW—ENE, parallel to the strike of the Central Mountains which is traceable from the Zala Hill Region up to the Danube and probably extends well into the Danube—Tisza Mid-Region. Since the time of formation of this wide fault trough the brooks issuing from the Central Mountains have deposited and accumulated their clastic material and alluvium in it, forming alluvial cones. This alluvial cone-building activity of the tributary brooks traversing the Somogy Hill Region might have remained undisturbed till the Middle Pleistocene or the beginning of the late Pleistocene. The slow subsidence of the basin of the present Balaton and the progressive development of the watershed of the Somogy Hill Region that pushed the development of the hill landscape to a new direction may have set in at that time. Thenceforth, the surface waters no longer flowed across the Somogy Hill Region.

They ran southwards from the Balaton Highland and from the northern part of the Somogy Hill Region, i.e. in the direction of the ancient trough of the Balaton. In the area of the Somogy Hill Region a valley watershed came into being in former valleys, and new water streams started to run from the centre of the hill region southwards in order to join the Kapos and the Dráva Rivers.

However, the southern border of the late Pleistocene basin of Lake Balaton lay 1 to 3 km farther S, as compared with its present position. The loesses intermingled with the detritic material of Triassic dolomites and Permian sandstones that had been removed from the northern shore by solifluction and pluvionivation during the glaciations accumulated in the late Pleistocene basin of the Balaton. In the Würmian Glaciation the trough of the Balaton went on sinking, but the subsidence already affected a smaller area roughly corresponding to the present extension of the lake. After this new subsidence the loesses loaded with talus were redeposited still at the end of the last glaciation from the southern part of the basin, which was not involved in the recurrent sinking, into the present trough of the Balaton as a result of the processes of pluvionivation and solifluction. These stratified loesses mixed with talus and densely intersected by dolomite layers dip in the direction of the present Balaton (Fig. 85). This circumstance and the morphological position of the dells trending towards the Balaton permit us to confirm Bulla's earlier suggestion that the basin of the Balaton appears to have been formed as early as the last glaciation. And, as it was pointed out by Marosi and Szilárd, this subsidence had taken place in several phases, being interrupted several times in space and time. The lake's basin is therefore polygenetic.

According to Marosi we have thus to deal with several phases of the formation of depressions in the southern part of the Transdanubian Hill Region. Most ancient is the Dráva Depression, which is followed subsequently by the Upper Kapos—Kalocsa Depression, and the most recent are the depressions of Lake Balaton, the Sárrét, the Zámoly Basin and the Lake Velence. This lateral succession, the members of which are gradually more recent when tracing them from S to N, subsequently served as a base level of erosion and sedimentary basin for the streams running from NW and N. The geologists and geophysicists indicate gravitation peaks between these longitudinal depressions as it is referred to by Marosi. This would mean that the structure of the basement is reflected in the top sediments and the surface features. Marosi and Szilárd consider that the landscape of the Somogy Hill Region reflects the structure of the basement but the valleys have been modelled by erosive and derasive processes.

In the area of Inner Somogy most of the present surface features are characterized by the abundance of the half-bound sand forms which have evolved on the sandy alluvial fan. These forms are dissected by two smaller ridges extending N—S and are split into two parts by a longer ridge (Marcali Ridge) consisting of Pliocene (Pannonian) clays and sands covered by a thick layer of slope loesses (Fig. 86). The western part of the territory of Outer Somogy is characterized by meridional, Pliocene, clayey-sandy ridges, while its eastern part, by highly elevated platform ridges situated between valleys trending NW—SE and roughly perpendicularly to it. On the northern faces of the platform portions the Pannonian sediments are found high

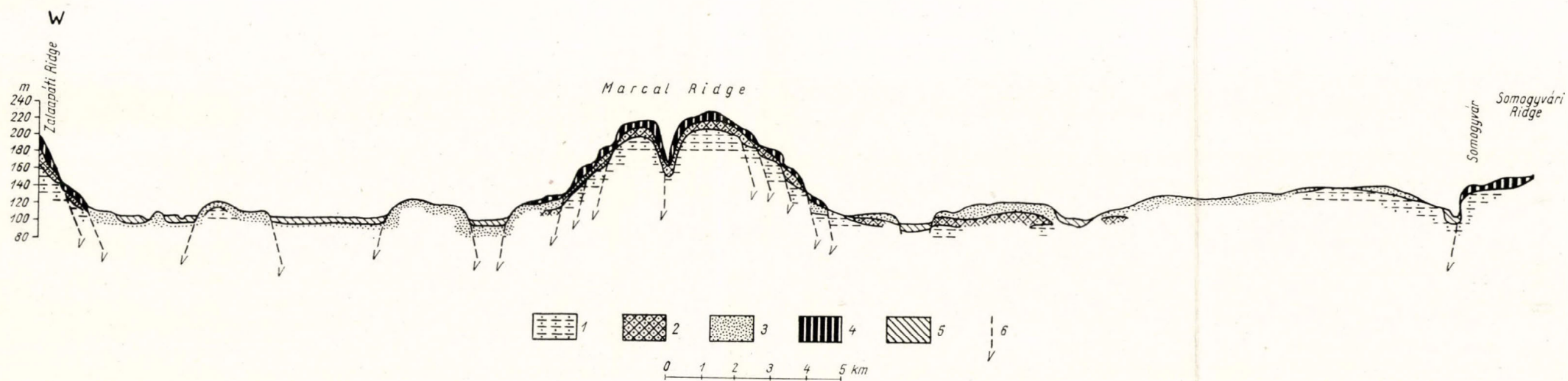


FIG. 86. W—E section Inner Somogy (according to S. Marosi)

1 — Upper Pannonian deposits (sand, clay), 2 — upper Pliocene cross-bedded sand, 3 — Pleistocene fluvial sand, mixed with fine-grained gravels; its wind-blown is marked by surface "kovárvány" (red-banded sand) and cryoturbation phenomena, 4 — Pleistocene loess, sandy loess, and slope loess, 5 — alluvial deposits (sand, silt, clay, peat); 6 — fault zone

above the valleys, while on their southern [edges the] Pannonian beds subside gradually by steps well below the alluvium of the transverse valleys (Fig. 87). On the other hand, in the eastern part of Outer Somogy the

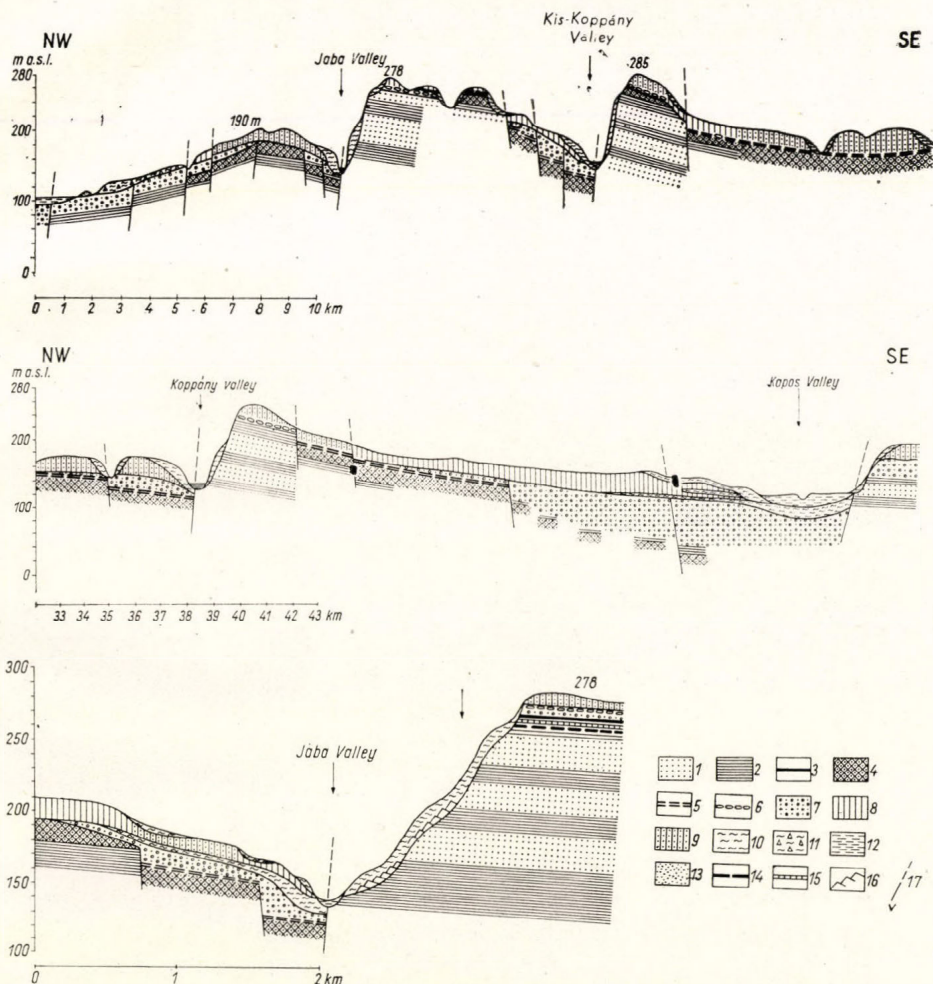


FIG. 87. N—S section across Outer Somogy, according to J. Szilárd

1 — Upper Pannonian sand, 2 — Upper Pannonian clay, 3 — red clay, 4 — upper Pliocene (Astian) cross-bedded sand, 5 — upper Pliocene greyish-yellow foliated sand, 6 — travertine, calcareous concretion, 7 — Pleistocene coarse sand, 8 — loess, 9 — sandy loess, 10 — slope deposits, 11 — slope deposits with coarse dolomite gravels, 12 — alluvial deposits, 13 — running sand, 14 — lignite-bearing clay, 15 — sand bank, 16 — slope deposits of landslide mechanism, 17 — fault zone

surfaces of the slope loesses covering the Pannonian deposits exhibit a series of derasional and cryoplanational steps (Fig. 65). The loess cover of the Somogy Hill Region consists, irrespective of the plateau loesses having limited extension, mostly of slope loesses stratified parallel to the present slope of



FIG. 88. Detail of a meridional valley from the Somogy Hill Country. (Photo Z. Szilárd)



FIG. 89. Type of the broad derasion valleys (dells) representing, a transition to meridional valleys. (Photo J. Szilárd)

the surface and attaining 10 to 30 m in thickness. The smaller valleys incising the surfaces of the meridional valleys and of the ridges between them were widened in the last glaciation chiefly by means of derasion. The larger valleys are dissected by derasional terraces, while the smaller ones have evolved to broad, dish-shaped dells (Figs. 88, 89). On the gentle slopes,

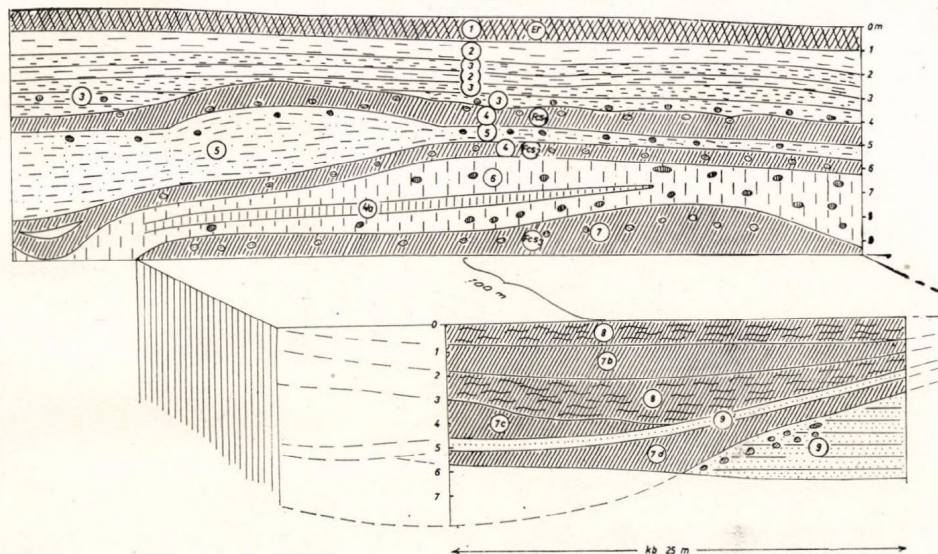


FIG. 90. Buried dell cross-section of the quarry of the Pécsi street brickworks at Kaposvár, according to Pécsi

1 — Brown clayey forest soil, 2 — slightly bedded loess with humic spots, 3 — slightly bedded loess with spots of coal and coffee-brown molehills, 4 — fossil chernozem with light molehills where soil formation of medium degree has taken place, 4a — slightly humic loess zone, 5 — bedded sandy loess with molehills, 6 — light-yellow loess penetrated by numerous dark molehills, 7 — fossil chernozem; 7b, 7c — chernozem soil, formed in situ, of a dell, 7d — chernozem with molehills, at the sole of a dell; 8 — chernozem material affected by ablation and solifluction, 9 — thin-bedded sand (with *Coelodonta antiquitatis*)

both derasional and erosional valleys have been extensively filled (Fig. 90). Outer Somogy can be characterized as an erosion-derasional hill region; the evolution of these forms has been largely promoted besides erosive, derasional and deflational processes, by the tectonic movements.

Owing to the large-scale decrease of the forest cover in modern times, a considerable amount of materials is redeposited and soils are removed by the grooving action of the soil erosion, and even more by the degrading soil erosion proceeding as a result of tillage on the slopes and ridges. In addition the soles of the major dells and those of erosion-derasional valleys are subjected to accretion even today.

(ii) LAKE BALATON

On the basis of morphological and palaeobotanical research, the following information can be given, as a short summary, about the formation of Lake Balaton (Marosi, Szilárd 1958). As it was shown earlier by B. Bulla and

A. Kéz, the basin of the lake must, by all means, have been formed already during the Last Interglacial, for large amounts of solifluction-pluvionivation deposits deriving from the Balaton Highland had accumulated in this basin. In addition, since the well stratified slope loesses (*grèzes litées*) densely interrupted by thin dolomite layers along the southern shore of Lake Balaton also dip towards the trough of the lake, we have to suppose that the trough

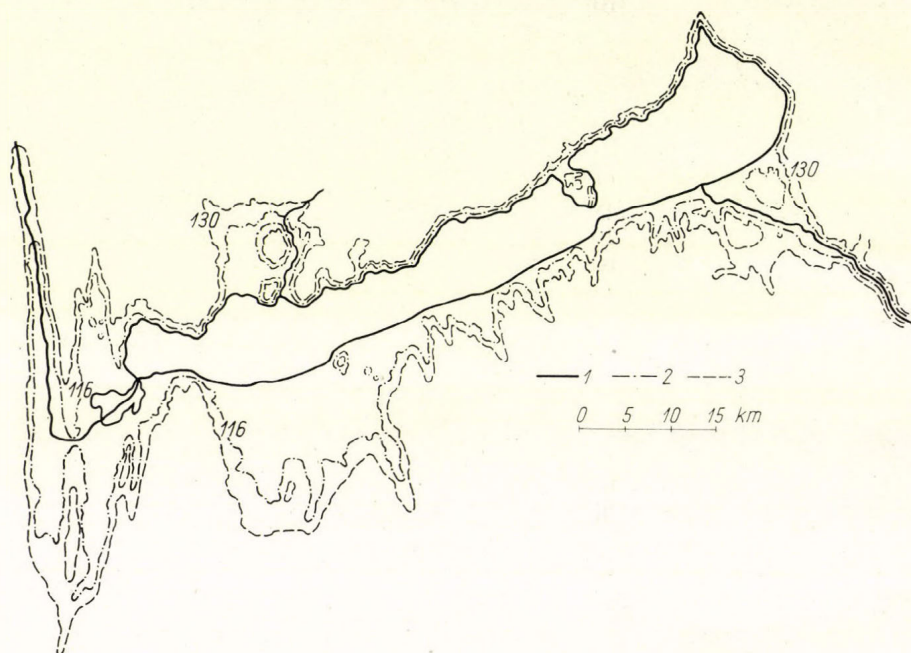


FIG. 91. Limits of abrasion activity at the presumed highest water level of the ancient (late Pleistocene) Balaton, according to B. Bulla

1 — Present-day beachline of Lake Balaton, 2 — evidenced limit of abrasion activity (116 m a. s. l.), 3 — presumed limit abrasion activity (132 m a. s. l.)

of the Balaton re-subsided still in the second half of the Last Glaciation. The Lower Zala River appears to have joined the Balaton at that time (Góczán 1960a, b). The partial filling of the trough with water is likely to have taken place in the late Würm glaciation and in the postglacial (Alerød). The Balaton Basin, formed in this way, was filled with water supplied by the brooks issuing from the northern slope of the lake and by the precipitations of postglacial times (Zólyomi 1952). Since in postglacial times the basin initially had no drainage, a water amount larger than that of the present Balaton may have accumulated in it. The more extensive postglacial water table of the Balaton results from this fact. At that time the water level of the Balaton was, as stated by Lóczy, Cholnoky, Bulla and Kéz, at least 6—8 m higher than the present average. At this higher level the lake inundated the southern lagoons and bays, to-day already dried up. The Balaton comprised

the Little Balaton, where the waters of the lake had ingressed well into the valley of the Lower Zala River, as well as the Nagyberek and several smaller lagoons on the southern shore of the lake (Fig. 91). The lake's waters also flooded the Tapolca Basin on the northern shore where the volcanic outlier shot out like islands from the water. This higher water level of the Balaton is testified by the abrasional levels occurring on the northern shore, and by the higher sand-riffs (lidos) that can be detected in several points of the southern shore. The lower barrier beach systems cutting off the lagoons along the present southern shore of the lake were built up during Holocene times. The cutting-off of the lagoons has led to the formation of peat and swamps. According to Szilárd and Marosi the Balaton has found its drainage through the Sió Valley towards the valley of the Sárvíz in modern times. The system of barrier beaches testifies that during the Holocene the water level of the lake has risen by only a few metres. In the driest hazel-nut phase, about 5000—6000 years ago, Lake Balaton almost dried up. Peat bogs were formed in its place. The existence of this meadow moor phase has been proved by drillings into the bottom of the lake (Zólyomi 1952). In our days the water level of the lake can be regulated artificially by means of the sluices of Siófok.

(iii) TOLNA HILL REGION

This is the most minutely fragmented rather highly elevated rolling landscape of the Transdanubian Hill Region. It is characterized by great relative altitudes and is situated between the Kapos River, the Mecsek Mountains and the Danube Valley. The hill country is also made up mainly of Pannonian deposits overlain by spots of travertines and by red clays which are covered by a thick sequence of fluvial sands, loesses and slope loesses. The surface of the present relief chiefly consists of thick fluvial sediments and of a likewise thick slope loess mantle. The Tolna Hill Region became mainland after the retreat of the Pannonian Sea and remained an area of erosion from the end of the Pliocene up to the beginning of the middle Pleistocene. As the surface of the Pannonian sediments got exundated, red clays were formed first. Below these clays a thin bank of travertines was cemented. The surface of the Tolna Hill Region was traversed and intensively dissected by faults trending NNW—SSE. The erosional paths of the palaeo-streams were controlled by these tectonic lines as revealed by the thorough investigations of L. Ádám (1960, 1962*b*). He suggests that during the middle Pleistocene the area underwent an over-all sinking so that the water streams coming from the direction of the Mezőföld and the Somogy Hill Region have built a wide-spread silty-sandy alluvial fan in the area in question. The local base level promoting the formation of alluvial fans was represented by the intensively sinking area of the Völgyiség situated immediately north of the Mecsek Mountains. In the southernmost part of the Tolna Hill Region and in the Szekszárd Hill Region no alluvial fan was formed because of the relative uplifting of the territory. At the time of its formation the alluvial fan of the Tolna Hill Region was still connected with those of the Southern Mezőföld and Western Mezőföld from which it was separated as late as in late Pleistocene times.

L. Ádám suggests that at the end of the Middle Pleistocene and in the late Pleistocene the activity of fluvial accumulation was superseded by the formation of loesses. An about 20 to 50 m thick loess cover intercalated by fossil soils developed on the alluvial fan surface of the Tolna Hill Region. The thick loess mantle commonly lies in the middle part of the slopes and at their foot. For the most part, this loess is bedded parallel to the slope.

According to L. Ádám, intensive tectonic movements took place simultaneously with loess formation. These recent tectonic movements exerted a considerable influence on the formation of the valleys of the hill region and changed the hydrographic patterns that had existed before late Pleistocene times. Simultaneously with the elevation and disintegration of the central areas of the hill region its west-eastern and the northern borders were faulted steplike and well separated from the adjacent areas.

According to Ádám, the evolution of the relief of the Tolna Hill Region has been decisively controlled by the accumulation of loesses. In his opinion, the loess cover of a thickness averaging 20—50 m and locally exceeding even 70 m represents an eolian formation. However, he also points out that the glacial solifluction has had an important part in the modelling of the surface relief simultaneously with eolian accumulation of loesses. The latter process has provoked the degradation of the tectonic steps. The present hydrography of the hill region was formed at the end of the last glaciation, while the peculiar microforms of the thick loess mantle evolved during the Holocene. Since the clearing of the forest cover, anthropogenous influences, such as agriculture have accelerated the karsting of the loess surfaces, the erosive fragmentation of slopes by ravines and gullies and the areal degradation of the soil cover over vast areas. Owing to the pronounced relative altitudes of the different points of the hill region (150 to 200 m), the larger showers and cloud bursts cause catastrophic damages. The study of the processes modelling actually the surface of the hill region has become a task of primary importance for preventing large scale soil erosion. The geomorphological methods necessary for a rational intervention are being studied by L. Ádám.

f) The Evolution of the Little Plain

We have assigned the Győr Basin, the Győr—Tata Terrace Region and the Marcal Basin to the Little Plain in the strict sense. Although the new physiographic subdivision of Hungary by landscapes does not include the gravel sheet beyond the Rába which had earlier been attached to it, nor the area of Kemeneshát, their geomorphological history is still closely linked with that of the Little Plain. Therefore, we shall discuss them together under this heading.

In terms of geology and geomorphology, the basin of the Little Plain is an area of rather young Tertiary and Quaternary subsidence. Its central part, the Győr Basin represents an alluvial plain having been accreted up to the present time, whereas the Győr—Tata Terrace Region is an area where accumulation took place followed by denudation in recent times. The Marcal Basin belongs to the category of plains showing the features of degraded basins.

The basement of the Little Plain basin is represented by crystalline schists lying at a depths of 1000 to 3000 m E of the line of the Rába River. They correspond to a deeply buried portion of the core of the Eastern Alps. East of the Rába line, the basement is composed of the likewise deeply subsided blocks of the Transdanubian Central Mountains. The subsidence of the Mesozoic blocks began already in the early Tertiary, while the western part having a crystalline basement began to sink only at the end of late Tertiary in Miocene-Pliocene times (Kőrössi). In the basin portion situated beyond the Rába the morphogenesis of the basin began by the deposition of Tortonian kalk, and Sarmatian limestones and by a slow sinking in the second half of the Miocene. However, the definitive subsidence of the basin took place during the Pannonian transgression, at the beginning of the Pliocene. Yet before the subsidence, it was mainland for a short time. The fast subsidence of the Little Plain basin stopped at the end of the Upper Pannonian epoch, and the basin somewhat uplifted, owing to which the inland sea withdrew (lower and middle parts of the Levantine stage). During the upper Pliocene a 50 to 150 m thick series of fluviolacustrine deposits spread over the Upper Pannonian sediments throughout the basin. When judging by the measurement of stratification, this deposition was the result of sedimentation proceeding from the north to the south. In the Marcal Basin this process was associated with a deposition trending E—W (E. Szádeczky-Kardoss 1938). These sediments are overlain by extensive gravel sheets deposited through a considerable erosional unconformity. They were transported from the Alps in an opposite direction, SW—NE. Accordingly, two pronounced unconformities can be detected in the Little Plain after the regression of the Pannonian Sea; the first one between the first Upper Pannonian beds and the very thick cross-bedded sands, the other one between the cross-bedded sands and the overlying gravel sheet. The basalt caps of the Marcal Basin resting on Pannonian sediments may have formed at the time of the formation of the first unconformity, while the marginal basalt tuffs of the Marcal Basin were deposited on the cross-bedded sands themselves, after, or during a much later erosive degradation. The Keszthely—Gleichenberg watershed developed before the formation of the gravel sheet, and the second erosional unconformity can thus be related to important crustal movements. E. Szádeczky-Kardoss (1938) earlier considered this unconformity to lie between the Dacian and the Levantine stages, whereas we now regard it as a marker of the upper Pliocene—Pleistocene boundary.

We have thus to make allowance for an entirely new phase, i.e. for the deposition of mainly coarse sediments which started with the Pleistocene in the Little Plain. These deposits had their source area in the catchment area of the rivers issuing from the Eastern Alps and gave rise to vast alluvial fans in the area of the Little Plain, so much so, that the Marcal Basin came to be accreted up to the level of the basalt-capped monadnocks (E. Szádeczky-Kardoss 1938). This accumulation was chiefly due to the Rába River and its tributaries carrying their waters towards the Palaeo-Danube. In this period the Danube also built a huge gravelly alluvial fan in the Győr Basin and in the Győr—Tata Terrace Region. The remnants of this Early Pleistocene alluvial fan are represented by the Parndorf Plateau and the terraced monadnocks

of Győr—Tata (Fig. 5). To judge by the position of the marginal terraces of the Little Plain, the formation of this enormous alluvial fan lasted up to the Middle Pleistocene, probably till the Mindel—Riss interglacial (Pécsi 1956—1959). From this time on, the central part of the Little Plain, the Győr Basin, had vigorously subsided and since then the more recent Little Plain alluvial fan of the Danube has evolved in its area. The larger part of this alluvial fan is the territory of the Csallóköz, in Czechoslovakia, the smaller part being situated in the areas of the Szigetköz, the Moson Plain and the Fertő-Hanság Basin in Hungary. In the Győr Basin the younger and older Danube deposits form, as a whole, a 50—200 m thick sandy-gravelly sediment suit (Fig. 92). The degradation of the Marcal Basin and especially of the Győr—Tata Terrace Country by erosion and derasion and their transformation into a degraded plain has continued since the subsidence of the central part of the Little Plain, i.e. the Győr Basin. However, the basalt-capped monadnocks show that in the Marcal Basin this degradation began already in the second half of the Early Pleistocene period.

The Kemeneshát gravel sheet of the Rába and its gravel sheet on the eastern margin of the Marcal Basin were formed simultaneously with the formation of the older alluvial fan of the Danube (Góczán 1962). While these widespread gravel sheets were being deposited, 3 to 4 terraces of the Danube and the Rába may have been formed in the mountainous reaches of the river. In the areas outside the Győr Basin, on the other hand, 2 to 3 younger terraces dating from the Riss—Würm interglacial came into being. Accordingly, the modelling of the Little Plain was largely controlled by the vigorous sinking of the Győr Basin during the Middle Pleistocene resulting in the alteration of the Győr Basin into a perfectly planated alluvial plain where smaller ill-drained basins have appeared between the alluvial fans (Fertő-Hanság Basin). In this period the predominant modelling agent in the Marcal Basin and the Győr—Tata Terrace Region was represented chiefly by erosive deepening and valley formation during the interglacials, and by degradation of slopes through pluvionivation-solifluction, dell formation and deflation during the existence of the climatic types of the glaciations (Pécsi 1962b). On the plain surfaces of the terraces and alluvial fans, very important fossil form features of the cryoturbation process can be observed (Figs 42, 46, 50—51). During the Holocene, the widespread flood plains have been the scene of fluvial accretion; the ill-drained smaller basins have been subjected to peat formation, swamping and meadow clay formation, while during the drier period of the early Holocene, blown-sands were deposited on the surfaces of the alluvial fans. Most soils of the Little Plain were formed in the Holocene.

(i) MORPHOGENESIS OF THE BASALT VOLCANO RUINS IN THE LITTLE PLAIN

The landscape beauty, the geology and the peculiar evolution of the basalt volcano ruins of the Marcal Basin awoke the attention of the research workers at an early date. Genetically these ruins have been classified as *stratovolcanoes* (Somló and Ság-Hills) and as *tuff hillocks* (L. Lóczy). The tuff hillocks are situated in the western part of the Marcal Basin, mostly on the slope of the Kemeneshát (tuff hillocks of Kissomlyó, of Gérce-Sitke, hillock of Szergény-

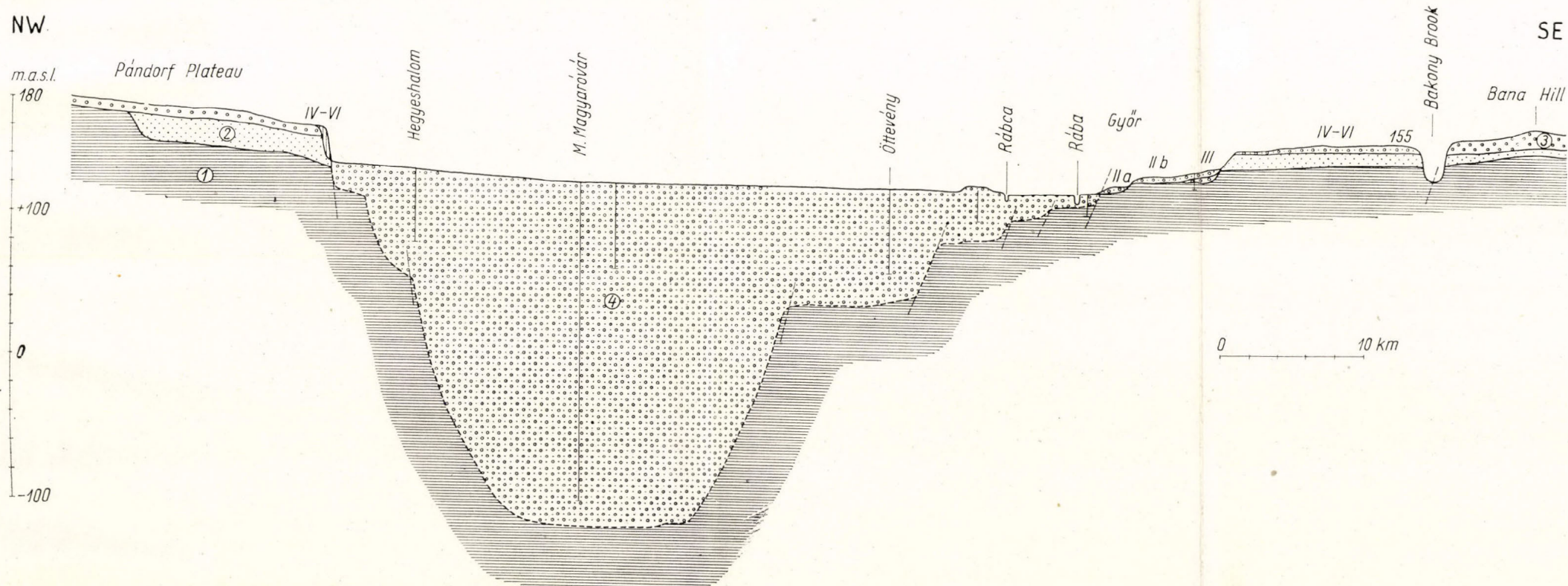


FIG. 92. Diagonal section across the Little Plain between the Pándorf Plateau and the terraced island mountains of Bana-Bábolna. (Constructed by using the boring data of the Hungarian Geological Institute. 1 — Pannonian beds, 2 — upper Pliocene cross-bedded sand, 3 — older alluvial gravels, 4 — mainly sandy and gravelly fluvial sediments filling the Győr Basin; IIa, IIb, III — Danube terraces, IV—VI — remnants of the early Pleistocene alluvial fan of the Danube)

Kemenesmagas and tuff field of Marcaltő). The tuff hillocks of Kissomlyó of Gércé-Sitke contain minor amounts of lavas, too, and together with the stratovolcanoes they form buttes proper. The reconstructed cross-section of the basalt-capped monadnocks has been plotted by the geologist L. Jugovics (Fig. 93).

The basalt volcanism of Transdanubia and the forms it has produced have been discussed most thoroughly by I. Vitális and L. Lóczy. Lóczy suggests that all the volcanoes were formed in the upper Pliocene as a result of recurring

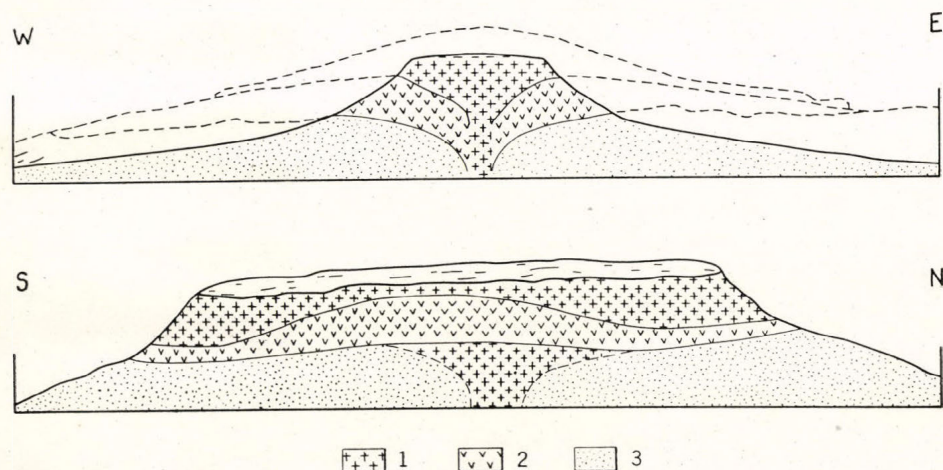


FIG. 93. Ruins of the basalt volcano of Sághegy (according to L. Jugovics)

1 — Basalt, 2 — basaltic tuff, 3 — Upper Pannonian sand and clay

eruptions. However, the tuff hillocks on the margin of the Marcal Basin are considered by him to be of much more recent origin. This author ascribes their formation to the lower Pleistocene, to a period following the deposition of the Kemeneshát Gravel Sheet since also Kemeneshát gravels could be observed as intercalations within the Sitke tuffs. Lóczy's correct statements are substantiated by the more recent terrace-morphological studies in the Little Plain, as well. Moreover, they have furnished evidence for the more exact determination of the dates of the youngest eruptions of basalt tuffs.

The volcanic activity responsible for the basalt tuff hillocks on the Kemeneshát Gravel Sheet can be related to the more intensive crustal movements that preceded the subsidence of the Győr Basin.

The geomorphology of the basalt-volcanic monadnocks in the Marcal Basin has not been studied thoroughly by anyone after Lóczy's work. Recently the unpublished paper of P. Bokor includes partial geomorphological observations. The common features in the morphologically variegated monadnocks are due to the basalt cap extending like a shield volcano which has spread over the Pliocene surface made up of loose Pannonian deposits. Since the loose sediments surrounding the shield volcano were easily removed

by denudation, the lava sheet emerged from its environment attesting to the orography that existed at the moment of the lava effusion. However, the external forces (erosion, deflation, cryoplanation) destroyed not only the environment consisting of more loose rocks, but also the surface and the borders of the *volcanic cover* depending on its thickness and extension. This resulted in the formation of denuded monadnocks having the shape of a cone or a truncated cone.

(ii) MORPHOGENESIS OF THE TRANS-RÁBA GRAVEL SHEET

In terms of geomorphology, this is a gravel plain stretching far out southwards between the south-western marginal landscape of the Little Plain, the Hungarian spurs of the Eastern Alps and the valley of the Rába River. In the geographical literature it is referred to as "Trans-Rába Gravel Sheet" and "West Hungarian Gravel Sheet" which was earlier discussed by L. Lóczy Senior, J. Cholnoky, E. Szádeczky-Kardoss, and by the Austrian scientist, Winkler-Hermaden. According to the more recent investigations of L. Ádám (1962a) who relies upon the studies of the above-mentioned researchers, the morphogenetical history of this area can be outlined as follows:

The Trans-Rába Gravel Sheet is divided into a higher (220 to 320 m) level and a lower one (150 to 200 m). The gravel sheet lying at the lower level as a slightly dissected plain, faces the plane of the Rába. On the basis of his detailed mineralo-petrographical and morphological investigations, Ádám confirms E. Szádeczky-Kardoss' opinion, as opposed to the earlier investigators (Lóczy Senior, Cholnoky, Bendefy). He suggests that the Trans-Rába Gravel Sheet is not uniform, but is composed of gravel sheets of alluvial fan character of different rivers of various ages (Fig. 94). The alluvial materials of the palaeo-Pinka, palaeo-Gyöngyös, palaeo-Répcse and Rába can clearly be separated from one another both lithologically and morphologically. The higher seated gravel sheets accumulated during the lower Pleistocene are connected with the Kemeneshát Gravel Sheet of the Rába. The lower Pleistocene tributaries of the Rába accumulated their gravelly deposits extending to the Kemeneshát Gravel Sheet of the Rába and locally even overlapping it (Pinka, Gyöngyös, Répcse). This gravel alluvial fan horizon, seated higher had formed before the Rába was cut down to a deeper level due to the subsidence of the Győr Basin in the middle Pleistocene. During Riss and Würm glaciations the Rába built an alluvial plain with two terraces, 8 to 10 km wide west of its present flood plain as testified by the morphological situation and the cryoturbation feature types. These two alluvial terraces are seated substantially lower than the surface of the Kemeneshát. The left bank tributaries of the Rába, keeping pace with the subsidence of the base level of the mean stream, fragmented their earlier alluvial gravel sheet seated more highly, and heaped up their gravel alluvia on the gravels of the late Pleistocene alluvial fan along the left bank of the Rába. The lower-seated gravel sheets of these tributaries were developed during the late Pleistocene even in two horizons (Ádám 1962a, Fig. 95). The 8 to 10 km wide gravel sheet composed of Rába gravels dips gently eastwards. It is connected by a low terrace benchland with the

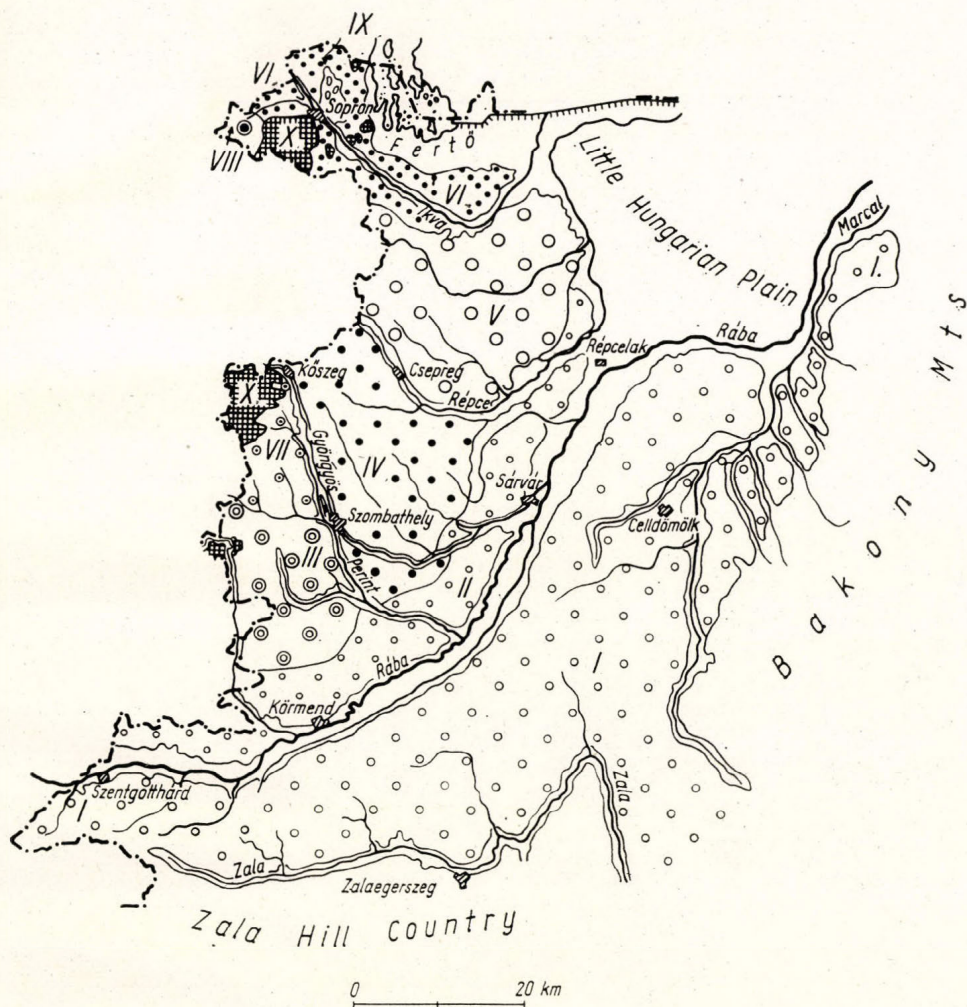


FIG. 94. Genetic map of the West-Hungarian Gravel Sheet, according to L. Ádám

I — Gravel sheet on the right bank of the Rába (Pleistocene, middle Pleistocene), II — gravel sheet on the left bank of the Rába (middle Pleistocene — late Pleistocene), III — gravel sheet of the Pinka (early Pleistocene) IV — gravel sheet of the Gyöngyös (early Pleistocene — late Pleistocene), V — gravel sheet of the Répce (middle Pleistocene — late Pleistocene), VI — gravel sheet of Ikva—Vulka (early Pleistocene — late Pleistocene), VII — angular sheet gravels (quartzites produced by weathering of crystalline schists) of the Kőszeg Mountains (late Pleistocene), VIII — Miocene gravel and conglomerate sheet of the Sopron Mountains (Helvetian), IX — Lower Pannonian gravel; X — Crystalline block mountains (Sopron—Kőszeg—Vas Mountains)

flood plain while farther to the NE, on the fringes of the Little Plain, it fits well into the Rábaköz alluvial fan.

The higher-seated alluvial gravels overlie, with very pronounced unconformity, the thick upper Pliocene fluvio-lacustrine sands characterized by *Unio Wetzleri*, which were deposited after the retreat of the Pannonian Sea. Accord-

ing to Ádám, this unconformity may also mark the boundary between the Pliocene and the Pleistocene. The lower-seated, more younger alluvial gravels partly rest upon the upper Pliocene cross-bedded sands, and partly overlie directly the Upper Pannonian clays and sands.

Ádám suggests that the connection with the gravel sheet of the Kemeneshát was broken off as a consequence of the formation of a trough-like depression, the axis of which runs parallel to the present Rába Valley. This subsidence was essentially synchronous with that of the Győr Basin which subsided in the Mindel—Riss interglacial and was occupied and accreted by the Rába, gradually shifting from the Kemeneshát.

On the higher horizon of the West-Hungarian Gravel Sheet showing more vivid relief, the processes of solifluction reshaped the slopes and the valley sides to a considerable degree during the Pleistocene glaciations and carried great amounts of material towards the valley soles. The gravel sheets seated both higher and lower are covered with glacial loams forming large spots and having been redeposited by solifluction. On the surface of the lower-seated gravel sheet plain the solifluction phenomena play a subordinate role while the forms of cryoturbation show very abundant varieties being spread regionally. Large (1 to 3 m) polygons, ice wedges and sacs exceeding 2 to 3 m in diameter as well as dish-shaped and kettle-shaped cryoturbation features measuring several metres in diameter are encountered at every step in the exposures. The Holocene erosive processes have only slightly modified the relief patterns of the plain which had considerably been modelled by processes of solifluction and pluvionivation during the last Glaciation. The plain surface covered with brown glacial loam and with spots of loess-like clayey sediments is characterized by slowly seeping brooklets, flat brook valleys as well as by flat valley forms being modelled, in turn, by means of erosion and derasion.

(iii) VAS RIDGE AND KEMENESHÁT

This is a terraced alluvial fan stretching deep into the body of the Little Plain and emerging considerably above its environment between the valleys of the Rába, the Zala and the Marcal Rivers. The hill region with marked relative altitudes (180 to 200 m) dissected by terraces along the western frontier of the country and by a dense valley network in the region of the main valleys, is called Vas Ridge. Farther NE this landscape turns into a wide, flat gravel alluvial fan with gradually dropping relative altitudes.

The geological structure of the Vas Ridge is well exhibited by the intensively dissected tributary valleys. Its basement is made up of Upper Pannonian greenish clays and banked sand layers, while near the Graz Basin, in the proximity of the national boundary, it is composed of gritty, fine-gravelled strata which are successively overlain by intensively bedded sands dating from the end of the Pliocene and then by late Pliocene gravels and Pleistocene terrace gravels at the top. The surface represented mostly by slopes is covered with glacial loam redeposited by solifluction. In the structure of the Kemeneshát, the Upper Pannonian sands and clays are found only at few localities. The basement of the wide-spread gravel sheet is represented by cross-bedded sands which are locally characterized by *Unio Wetzleri*, but are chiefly barren at other localities. The alluvial gravels overlie it though unconformably.

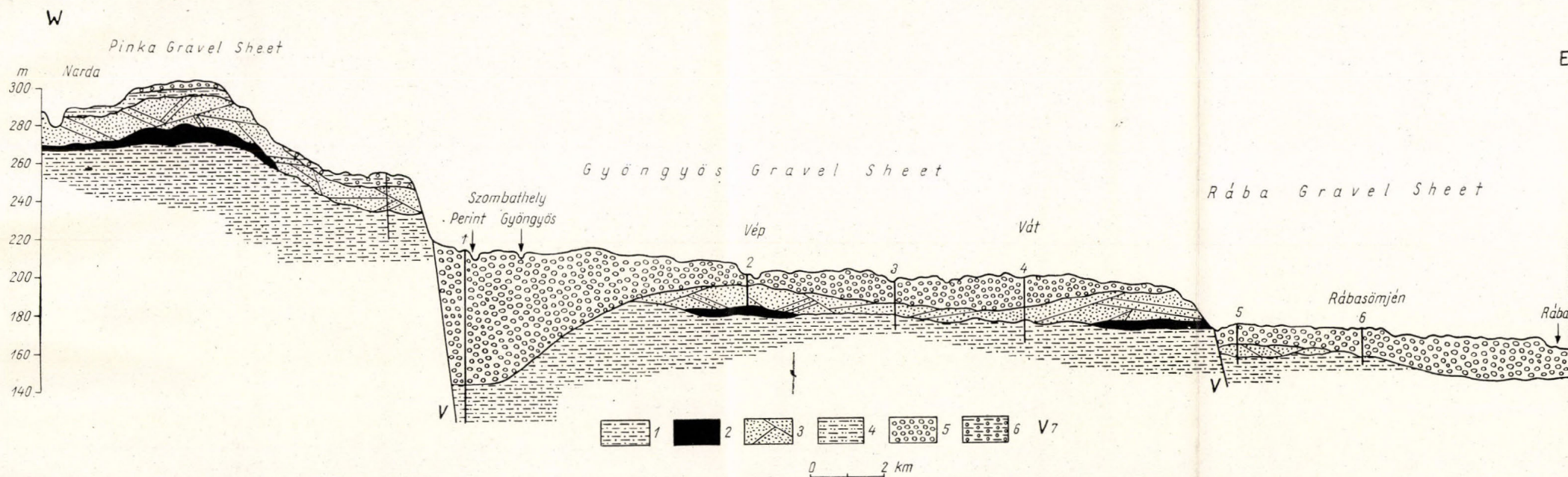


FIG. 95. W—E cross-section across the gravel sheet of the Trans-Rába Region from the Pinka River up to the River Rába Region (according to L. Ádám)

1 — Upper Pannonian clay, sand, 2 — brownish-grey, silty, sandy, clayey rock suit, the final deposits; of the Upper Pannonian lacustrine, 3 — brownish-grey, greyish-brown, obliquely stratified upper Pliocene fluvial sand characterized by *Unio Wetzleri* fauna, 4 — yellowish-grey, greyish-yellow, markedly calcareous, clayey-sandy series interrupted by fen clay, presenting the top of the upper Pliocene cross-bedded sand, 5 — Pleistocene gravel sheet, 6 — glacial loam with brown gravel redeposited by solifluction, 7 — fault zone

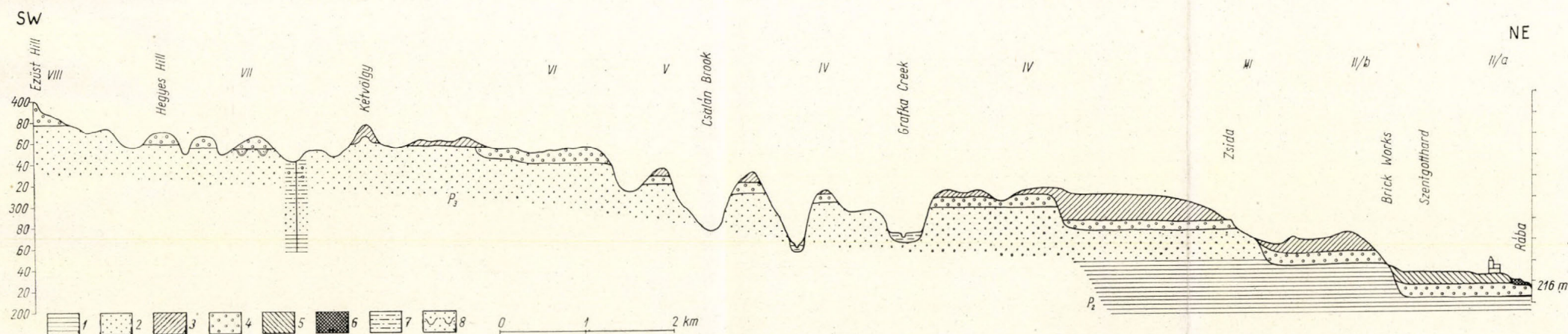


FIG. 96. SW—NE cross-section across the Vasi Ridge from the Ezüst Hill up to Szentgotthárd according to S. Somogyi

1 — Pannonian clay, sandy clay, 2 — upper Pliocene and Pleistocene fluvial sand, 3 — Pleistocene loam and brown soil, 4 — gravel of the Rába-River, 5 — alluvium and slope debris of the Rába, 6 — Holocene deposits, 7, 8 — terraces I—VIII of the Rába from the Holocene up to the upper Pliocene

On the surface of the Kemeneshát there are smaller isolated hillocks of basalt tuffs and lavas which were formed on the Pliocene-Pleistocene boundary. The gravel sheet is covered with spots of a few metre thick glacial loam.

The evolution of this landscape, which is intimately linked to that of the adjacent areas, has been thoroughly studied, on the basis of the stratigraphic conditions, by L. Lóczy Senior (1913), J. Chalnoky (1937), I. Ferenczy (1924), J. Sümeghy (1939, 1955), E. Szádeczky-Kardoss (1938), L. Strausz, A. Kéz and S. Láng, and by an Austrian scientist, Winkler-Hermaden. These investigations have outlined the main features of the geomorphological evolution, but several questions of detail, especially the chronology of the processes on the Pliocene-Pleistocene boundary as well as the up-to-date general views concerning the geomorphological evolution during the Pleistocene still require completion and modification. We can sum up the morphogenesis of the Vas Ridge and Kemeneshát by relying upon the results of the above-mentioned investigations and by taking into consideration Somogyi's relevant studies (1962a).

According to Somogyi the evolution of the surface of the Vas Ridge somewhat differs from that of the Kemeneshát, because while in the area of the Vas Ridge the Upper Pannonian green clays and banked sand layers are exposed in the roads cut into the deeper valleys, in the region of the Kemeneshát they are only known from deeper boreholes. The formation of the Vas Ridge is analogous to that of the hill ridge with 7—8 terraces between the Mura and the Rába Rivers in the area of the Graz Basin. The sediments of the Vas Ridge were deposited as littoral facies on the border of the Upper Pannonian Sea that was regressing towards the fault trough of the Dráva. The Alpine streams locally produced gravelly layers within the cross-bedded sands overlying the Upper Pannonian deposits of the Vas Ridge. During the upper Pliocene the palaeostreams of the Styrian Basin (Rába, Mura) deposited the higher seated gravel horizons mentioned by Winkler-Hermaden through unconformity upon the surface of these strata. In Hungary, we have found only a single representative of the gravel horizons mentioned just before, i.e. the Ezüst Hill horizon dating from the end of the Pliocene.

After the regression of the Pannonian Sea, in the area of the Styrian Basin and of the Vas Ridge the sedimentation trended SE towards the fault trough of the Dráva for a long time. In the area of the Little Plain, as already mentioned, the angles of dip measured in the cross-bedded sands show the redeposition of sediment material to have been directed similarly towards the Dráva fault trough (i.e. southwards). E. Szádeczky-Kardoss suggests that this direction of removal has changed since the Levantine times, that it has turned NE, towards the central part of the Little Plain, that sand layers have no longer been deposited, and that the accumulation of a coarse-grained gravel bed unconformably overlying the sands has set in instead. In our opinion, this unconformity and the appearance of the coarser gravel sediments indicate the setting in of a new process of denudation and sedimentation, as interpreted by E. Szádeczky-Kardoss and Winkler-Hermaden, too. However, we can conceive this process as the beginning of the Quaternary era the stages of which increase in range if going back in geological history.

During the first, longer half of the Pleistocene the huge alluvial fan of the Rába formed on the surface of the Kemeneshát as well as further E, up to the

foot of the Transdanubian Central Mountains (Somogyi 1962a, Góczán 1962), and the development of this large, coherent alluvial fan might have lasted until the Győr Basin markedly subsided in Mindel—Riss times. During the accumulation of the gravel alluvial fan of the Kemeneshát in the Little Plain, the area of the Vas Ridge and the Graz Basin was being subjected to the formation of terraced valleys. Hence, during the formation of the Kemeneshát gravel sheet, terraces IV, V, VI and VIII were formed in the afore-mentioned territories. In the area of the Vas Ridge eight terraces of the Rába can be observed between Szentgotthárd and the Ezüst Hill with the following relative altitudes (Fig. 96): terrace I, lower flood plain level, 2—3 m, higher flood plain level, 4—5 m; terrace II, 10 m; terrace III, 20—25 m; terrace IV, 50—60 m; terrace V, 90—100 m; terrace VI, 110—120 m; terrace VII, 130—140 m. Above the latter there follows terrace VIII, i.e. a horizon of the Ezüst Hill and the Katalin Hill having relative heights of 150—180 m. The terrace referred to here as terrace VII may date, together with all the higher terraces exempt from flood, already from the Pleistocene, as suggested by the presence of a sand surface affected by cryoturbation in its base.

In the northern and north-western foreland of the Kemeneshát the Rába Valley represents a tectonically controlled erosive valley, and so do the valleys of the Zala and the Marcal Rivers which run along the same line. The Kemeneshát terminates with an edge which is markedly cut down. There are sporadic terraces, too, but the alluvial fans of the partly erosive valleys, mostly dells, running from the surface of the Kemeneshát towards the Rába Valley are often so closely spaced that in some places they grow together like terraces, resulting in pseudoterraces. The southern and south-eastern boundaries of the Kemeneshát drop down through wide, terrace benchlands towards the Zala and the Marcal Rivers. These terrace horizons

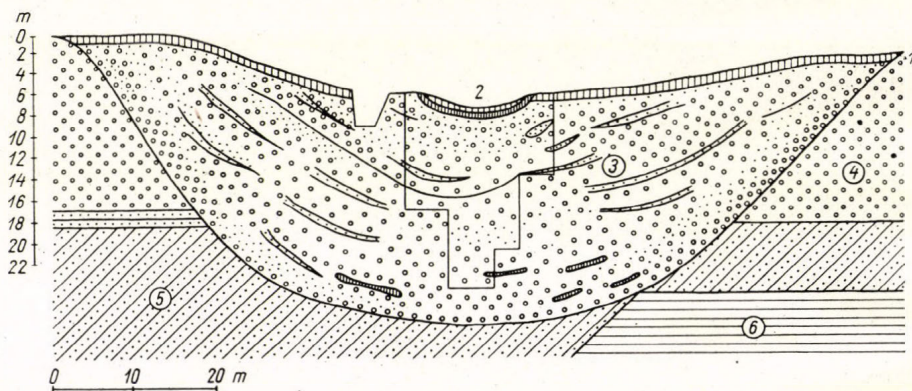


Fig. 97. Dell filled with loamy gravel. Large ancient dell on the Kemeneshát Gravel Sheet, reconstruction based on the exposure of the gravel quarry at Sárvár

1 — Clayey brown forest soil, 2 — humic sand filling the youngest derasion valley, underlain by buried brown forest soil, 3 — gravel coated by clay crust and bedded in light and dark brick-red clayey sand, the filling material of the ancient dell; it also contains Pannonian clay lumps, 4 — gravel of the Kemeneshát, material of the early Pleistocene alluvial fan of the Rába, 5 — upper Pliocene cross-bedded sand, with sandy clay in its upper horizon, 6 — Pannonian clay, with sandy clay at the top horizon

are covered by a thick suit of obliquely laminated glacial loam which is mixed in several points with gravel detritus. The glacial loam cover plunges from the lowest terrace horizon deeply below the present flood plain of the Zala Valley, indicating that during the last Glaciation the Zala Valley was filled up with sediment to a high level by means of slope wash, solifluction and pluvionivation. The actual features of the Kemeneshát Plateau have been developed since the Mindel—Riss interglacial period due to the more pronounced incision of the Rába, the Zala and the Marcal Rivers. During the Riss and Würm Glaciations, several types of periglacial cryoturbation features (4 to 5 m long ice wedges, polygonal sacs, ice cracks) appeared on the surface of the Kemeneshát, while on the borders as well as in the dells large-scale redeposition and accumulation of rock materials by solifluction took place (Fig. 97). On the surface of the Kemeneshát, clayey brown forest soils and red clayey soils were formed during the interglacials, as are under the current climatic type. These soils offered very favourable conditions for the setting in of processes of gelifluction during the glacial periods. The redeposition of the rock material on slopes caused the filling of most of the former erosional valleys and dells, and the eroded relief became considerably flattened owing to cryoplanation.

At the beginning of the Holocene, the area became completely covered by forest, but in historic times the forest cover became thin under the influence of agriculture, and the soil erosion as well as the degradation in dells revived again.

Accordingly, the surface of the present Kemeneshát and the Vas Ridge was modelled by erosive processes along fracture lines during the existence of warmer, humid climatic types, and by processes of solifluction during the dry-cold glaciations. The hill landscape of Kemeneshát affected by processes of erosion, derasion and accumulation has come into being in this way.

FUTURE PLANS

The Geographical Research Institute seeks to take a larger share in the long-term research plan of the geographical sciences by performing theoretico-methodological investigations destined to satisfy practical demands. Therefore, we shall complete the 1 : 200,000 scale geomorphological map of Hungary and start the geomorphological and soil erosion mapping on scale 1 : 25,000 in some areas of the country selected according to their economic importance. The elaboration of the necessary legend and methods has already been started. In the subsequent years we shall discuss our experiences also with the research workers carrying out similar work in the allied and related institutions.

We have eliminated the one-sidedness in the study of the relief and evaluate the relief, as a part of the physiographic environment, from the practical point of view as well. In this connection, we shall seek, on the other hand, to interpret the physiographical environment with all its factors in its complexity, to develop the scientific trend of the *complex physiographic landscape evaluation*. The first steps in this direction have been made recently by the members of the Physiographical Section.

This ambition requires the clarification of the fundamental principles of the complex physiographic landscape evaluation with a view to the practical requirements the development and amplification of its methodology.

Our current and future task is the compilation and publication of the monograph *Physiography of Hungary* prepared under joint auspices of the Hungarian physiographers and the representatives of the cognate sciences. Most manuscripts have already been received. Our further objective is to treat the Little Plain, the Transdanubian Hill Region and the region of Lake Balaton in the form of physiographical monographs.

BIBLIOGRAPHY

- ÁDÁM, L. (1953), Morfológiai vizsgálatok a Mezőföld Duna—Sárvíz közti területén (Morphological studies in the area between the Danube and Sárvíz of the Mezőföld), *FÉ* pp. 176—200
- ÁDÁM, L. (1954), A mezőföldi löszös területek karsztos formáiról (Karstic forms of loess areas in the Mezőföld), *FÉ* pp. 339—350, German and Russian summaries
- ÁDÁM, L. (1955a), Észak-Mezőföld geomorfológiája (Geomorphology of the northern part of the Mezőföld), *FÉ* pp. 403—426, German and Russian summaries
- ÁDÁM, L. (1955b), A Velencei-tó és a Zámolyi-medence kialakulása (Formation of Lake Velence and the Zámoly Basin), *FK* pp. 307—332, German and Russian summaries
- ÁDÁM, L. (1959a), A Móri-árok és északi előterének kialakulása és fejlődéstörténete (Formation of the northern foreland of the Mór Fault Trough and its history of development), *FÉ* pp. 277—307, German summary
- ÁDÁM, L. (1959b), A Móri-árok és északi előterének morfológiája (Morphology of the Mór Fault Trough and its northern foreland), *FÉ* pp. 417—431, German summary
- ÁDÁM, L. (1960), A tolnai Hegyhát kialakulása (Morphogenesis of the Hegyhát Ridge in Tolna), *FÉ* pp. 143—176, German and Russian summaries
- ÁDÁM, L. (1962a), A Rábántúli-kavicstakaró (Gravel sheet beyond the Rába), *FÉ* pp. 41—52, German and Russian summaries
- ÁDÁM, L. (1962b), A Tolnai-dombság (The Tolna Hill Country), *FÉ* pp. 74—78, German and Russian summaries
- ÁDÁM, L.—GÓCZÁN, L.—MAROSI, S.—SOMOGYI, S.—SZILÁRD, J. (1962), Néhány dunántúli geomorfológiai körzet jellemzése (Characterization of some geomorphological districts of Transdanubia), *FÉ* pp. 41—84, German and Russian summaries
- ÁDÁM, L.—MAROSI, S.—SZILÁRD, J. (1959), A Mezőföld természeti földrajza (Physical geography of the Mezőföld), *Földrajzi Monográfiák*, vol. II, Akad. Kiadó, Bp., 514 p., German and Russian summaries
- BACSAK, Gy. (1840), Az interglaciális korszakok értelmezése. I—III. rész. Időjárás (Interpretation on the interglacial periods. Parts I—III. Weather), pp. 8—16, 62—69 and 105—108
- BACSAK, Gy. (1942), A skandináv eljegesedés hatása a periglaciális övön (Influence of the Scandinavian glaciation of the periglacial zone), *M. Orsz. Met. és Földmágnassági Int. kisebb kiadv.* 467 p.
- BACSAK, Gy. (1944), Az utolsó 600 000 év földtörténete (Geological history of the last 600,000 years), *Beszámoló a Földt. Int. Vitaüléseinek munkálatairól*, pp. 221—269, In German
- BERG, L. Sz. (1953), Éghajlat és élet (Climate and life), Akadémiai Kiadó, Bp. 528 p. Translation from Russian
- BOGÁRDI, J. (1955), A hordalékmozgás elmélete (Theory on drift movement), Bp. 574 p.
- BOGÁRDI, J. (1958), Néhány újabb törvényszerűség a hordalékmozgás elméletében (Contribution to the theory of drift movement), *HK* pp. 241—253, German and English summaries
- BORSY, Z. (1953), A Bodrogek felszínének kialakulása (Morphogenesis of Bodrogek), *FÉ* pp. 409—419
- BORSY, Z. (1954), Geomorfológiai vizsgálatok a Bereg—szatmári-síkságon (Geomorphological investigations on the Bereg—Szatmár Plain), *FÉ* pp. 270—280
- BORSY, Z. (1959), A Bereg—szatmári vízrendszer kialakulása (Formation of the Bereg—Szatmár drainage system), *Közlemények a KLTE Földrajzi Intézetéből*, Debrecen, pp. 253—270, German summary
- BORSY, Z. (1961), A Nyírség természeti földrajza (The physical geography of Nyírség), *Földrajzi Monográfiák*, vol. V, Akadémiai Kiadó, Bp. p. 222
- BULLA, B. (1933), Morfológiai megfigyelések magyarországi löszös területeken (Morphological observations in loess areas of Hungary), *FK* pp. 169—201, German summary

- BULLA, B. (1934), A magyarországi löszök és folyóteraszok problémái (Problems of the loesse^s and the river terraces of Hungary), *FK* pp. 136—149, German summary, pp. 166—168
- BULLA, B. (1935), Néhány szó a poláris és szubpoláris tundraképződmények kutatástörténetéhez (Brief contribution to the history of investigations on polar and subpolar tundra formations), *FK* pp. 279—284, German summary
- BULLA, B. (1936), Teraszok és szintek a Duna jobbpartján Dunaadony és Mohács között (Terraces and levels on the right bank of the Danube between Dunaadony and Mohács), *MTA Mat. és Term. tud. Ért.* pp. 193—224, German summary
- BULLA, B. (1937—1938), Der pleistozäne Löss im Karpathbecken (Pleistocene loess in the Carpathian Basin), *FtK*, fasc. 7—9, 66 p. In German
- BULLA, B. (1939), Teraszvizsgálatok Budapest és Dunabogdány között. I—II. rész (Investigations on terraces between Budapest and Dunabogdány. Parts I—II), *FK* pp. 92—107, 176—190
- BULLA, B. (1941), A Magyar medence pliocén és pleisztocén teraszai (Pliocene and Pleistocene terraces of the Hungarian Basin), *FK* pp. 199—230
- BULLA, B. (1943a), Über die Ausbildung und das Alter des Balaton Sees (On the formation and the age of Lake Balaton), *FK*
- BULLA, B. (1943b), Geomorfológiai megfigyelések a Balatonfelvidéken (Geomorphological observations in the Balaton Highland), *FK* pp. 18—45
- BULLA, B. (1951), A Kiskunság kialakulása és felszíni formái (Formation and surface features of Kiskunság), *Földr. Könyv- és Térképtár Ért.* pp. 101—116
- BULLA, B. (1953), L'évolution des formes superficielles de l'Alföld (Evolution of the surface features of the Great Hungarian Plain), *Acta Geologica*, Tomus II. pp. 1—15.
- BULLA, B. (1954a), Általános természeti földrajz. II. köt. (General physiography. Vol. II.) Bp. p. 549
- BULLA, B. (1954b), A szilárdkéreg domborzata fejlődésének alapsajátságai és törvényei (Fundamental characteristics and laws of the development of crustal relief), *FK* pp. 89—102, Russian and English summaries
- BULLA, B. (1954c), A klimatikus morfológia területi rendszere (Regional system of climatic morphology), *FK* pp. 535—570
- BULLA, B. (1954d), Az elmélet és gyakorlat egységének kérdése és a hazai geomorfológiai vizsgálatok (The problem of unifying theory and routine viewed from the angle of geomorphological investigations carried out in Hungary), *FK* pp. 181—189
- BULLA, B. (1955), A magyar földrajztudomány útja a felszabadulás óta (The road of Hungarian geography after the liberation), *FK* pp. 193—217, German and Russian summaries
- BULLA, B. (1956a), A magyar föld domborzata fejlődésének ritmusai az újharmadkor óta a korszerű geomorfológiai szemlélet megvilágításában (Rhythms in the development of the relief of Hungary since the Tertiary period in the light of modern geomorphological aspects), *MTA Társ. Tört. tud. Oszt. Közl.* pp. 281—296
- BULLA, B. (1956b), Folyóteraszproblémák (Problems of fluvial terraces), *FK* pp. 121—141, German and Russian summaries
- BULLA, B. (1958a), A Balaton és környéke földrajzi kutatásairól (Geographical exploration of Lake Balaton and its surroundings), *FK* pp. 313—324, English summary
- BULLA, B. (1958b), Néhány megjegyzés a tönkfelszín kialakulása kérdésében (Some notes on the formation of peneplain surfaces), *FÉ* pp. 257—274, German summary
- BULLA, B. (1959), Humboldt és a földrajztudomány (Humboldt and the science of geography), *FK* pp. 193—195
- BULLA, B. (1960), Quelques problèmes géomorphologiques interglaciaires de la zone périglaciaire du Pleistocène (Some geomorphological problems concerning the interglacial phases in the periglacial zone of the Pleistocene epoch). *Studies in Hungarian Geographical Sciences*. Publishing House of the Hungarian Academy of Sciences, pp. 7—16, Russian summary
- BULLA, B. (1962), Tíz éves az MTA Földrajztudományi Kutatócsoport (On the 10th anniversary of the Institute of Geography of the Hungarian Academy of Sciences), *FÉ* pp. 1—17, Russian and English summaries
- BULLA, B.—MENDŐL, T. (1947), A Kárpát-medence földrajza (Geography of the Carpathian Basin). Bp. 611 p.
- CHOLNOKY, J. (1902), A futóhomok mozgásának törvényei (Laws of the movement of running sands), *FK* pp. 6—38, German text pp. 106—143
- CHOLNOKY, J. (1910), Az Alföld felszíne (The surface of the Great Hungarian Plain), *FK* pp. 413—436

- CHOLNOKY, J. (1918), A Balaton hidrográfiaja (Hydrography of Lake Balaton), *A Balaton Tud. Tan. Eredm.* vol. I, part II, Bp.
- CHOLNOKY, J. (1926a), A folyóvölgyekről (On river valleys), *MTA Mat. és Term. tud. Ért.* vol. XLII, pp. 101—110, German summary
- CHOLNOKY, J. (1926b), A földfelszín formáinak ismerete. Morfológia (The knowledge of the features of the earth's surface. Morphology), Bp. 296 p. 169 figures.
- CHOLNOKY, J. (1934), A folyók szakaszjellegének összefüggése a szabályozással és az öntözéssel (How do the course types of the rivers depend upon regulation and irrigation), *VK* 23 p.
- CHOLNOKY, J. (1937), Magyarország földrajza (The geography of Hungary), Bp. 529 p.
- CHOLNOKY, J. (1940), A futóhomok elterjedése (Distribution of running sands), *FK* pp. 258—294, German summary, figs. 29—55
- ERDÉLYI, M. (1955), A Duna-völgy nagyalföldi szakaszának víztároló üledékei (Aquiferous sediments of the Alföld section of the Danube Valley), *HK* pp. 159—169, German summary
- ERDÉLYI, M. (1960), Geomorfológiai megfigyelések Dunaföldvár, Solt és Izsák környékén (Geomorphological observations in the surroundings of Dunaföldvár, Solt and Izsák), *FÉ* pp. 257—276, Russian and German summaries
- GÓCZÁN, L. (1955), A Szentendrei-sziget geomorfológiai fejlődéstörténete (History of the geomorphological development of the Szentendre Island), *FÉ* pp. 301—311, Russian and German summaries
- GÓCZÁN, L. (1960a), A Tapolcai-medence kialakulástörténeti problémái (Morphogenetic problems of the Tapolca Basin), *FÉ* 1—30, German summary
- GÓCZÁN, L. (1960b), Közép-, Nyugat-Dunántúli felszínfejlődési problémák. (Morphogenetic problems of the middle-western part of Transdanubia.) *A Magyar Földrajzi Társaság XIV Vándorgyűlése Zalaegerszegen 1960-ban.* pp. 27—30
- GÓCZÁN, L. (1962), A Marcal-medence (The Marcal Basin), *FÉ* pp. 58—60
- GÓCZÁN, L.—MAROSI, S.—SZILÁRD, J. (1954), Adatok a kőzetminőség, az erózió és a tektonikus mozgások jelenleg ható felszínformáló szerepéhez, valamint a talajerózióhoz (On the morphogenetic role of rock quality, erosion and tectonic movements acting presently as well as on soil erosion), *FK* pp. 73—82, German summary
- JAKUCS, P. (1961a), Az Északi-középhegység keleti felének növényzete (Flora of the eastern half of the North-Central Mountains), *FÉ* pp. 357—377, German and Russian summaries
- JAKUCS, P. (1961b), Die phytocönologischen Verhältnisse der Flaumeichen Buschwälder Südostmitteleuropas, Akadémiai Kiadó, Bp. 313 p.
- JAKUCS, P. (1962), A domborzat és a növényzet kapcsolatáról (On the relationship between the relief and the vegetation), *FÉ* pp. 203—217, Russian and German summaries
- KÁDÁR, L. (1935), Futóhomok-tanulmányok a Duna—Tisza közén (Studies on running sands in the area between the Danube and the Tisza), *FK* pp. 4—15
- KÁDÁR, L. (1938), Die periglazialen Binnendünen des Norddeutschen und Polnischen Flachlandes *Comptes Rendus du Congr. Intern. de Géographie.* Amsterdam 1938. In German
- KÁDÁR, L. (1939), Tektonikus tájelemek az Alföldön (Tectonic landscape elements of the Great Hungarian Plain) *FK* pp. 342—348, English summary pp. 349—351
- KÁDÁR, L. (1954a), A szél felszínalakító munkája. Fejezet Bulla B.: Általános természeti földrajz II. köt.-ben (The morphogenetic role of the wind. In Bulla, B.: General physiogeography, Vol. II.), Bp. pp. 206—245
- KÁDÁR, L. (1954b), A lösz keletkezése és pusztulása (Formation and removal of loess), *Közlemények a KLTE Földrajzi Intézetéből*, 19. sz. Debrecen, 27 p.
- KÁDÁR, L. (1955a), Das Problem der Flussmäander (Problem of fluvial meanders), *KLTE*, no. 21. ACTA, 24 p.
- KÁDÁR, L. (1955b), A folyókanyarulatok elmélete és a hegységek áttörésében való szerepe (Theory of meandering and its function in cutting through mountains), *Dunántúli Tud. Gyűjtemény*, 5. sz. Pécs. 32 p.
- KÁDÁR, L. (1956a), Die Abhängigkeit der Terrassen und der Lössbildung von den quartären Klimaveränderungen in Ungarn, *Biuletyn Peryglacjalny*, Łódź, pp. 371—404
- KÁDÁR, L. (1956b), A magyarországi futóhomok-kutatás eredményei és vitás kérdései (Results and some unsettled questions of investigations on blown sands in Hungary), *FK* pp. 143—163, Russian and English summaries
- KÁDÁR, L. (1957), Die Entwicklung der Schwemmkegel *Petermanns Geogr. Mitt.* pp. 241—244, in German

- KÁDÁR, L. (1960a), Hordalékmozgás és folyószakaszjelleg (Drift movement and river course types), *FÉ* Lecture and discussion pp. 309—366, German summary pp. 367—379
- KÁDÁR, L. (1960b), Climatological and other conditions of loess formation, *Studies in Hungarian Geographical Sciences*, Publishing House of the Hungarian Academy of Sciences, Bp. pp. 17—24
- KÁRPÁTI, I.—PÉCSI, M. (1959), Correlations between the succession of natural groves and the flood-plain levels on the Great Hungarian Plain, *Acta Biologica* Suppl. 3.,
- KÁRPÁTI, I.—PÉCSI, M.—VARGA, GY. (1962), A vegetáció és az ártéri szintek fejlődésének kapcsolata a Dunakanyarban (Relationship in the evolution of vegetation and the flood-plain levels at the Danube bend), *BK XLIX. k.* pp. 298—308, German summary
- KEREKES, J. (1941), Hazánk periglaciális képződményei (Periglacial formations of Hungary), *Beszámoló a Földt. Int. Vitailéseinek munkálatairól*. Bp. pp. 97—142, Comments pp. 142—149
- KÉZ, A. (1933a), A budai Várhegy terasz kavicsa (Terrace gravels of the Vár Hill in Buda), *FK* pp. 266—268
- KÉZ, A. (1933b), A Duna visegrádi áttörése. (Cutting through by the Danube at Visegrád), *MTA Mat. és Term. tud. Ért.* pp. 713—751, German summary
- KÉZ, A. (1934), A Duna Győr—budapesti szakaszának kialakulásáról (On the formation of the Győr—Budapest reaches of the Danube), *FK* pp. 175—193, German summary pp. 218—220
- KÉZ, A. (1935), Vízfolyások szakaszjellegei (Course types of streams), *FK* pp. 344—350, English summary pp. 350—354
- KÉZ, A. (1937), Flussterrassen im Ungarischen Becken (River terraces in the Hungarian Basin), *Petermanns Geogr. Mitt.* pp. 253—256
- KÉZ, A. (1939), A Duna balparti teraszai Komárom és Szob között (Terraces of the left bank of the Danube between Komárom and Szob), *FK* pp. 351—360, French summary pp. 360—361
- KÉZ, A. (1942), Az erózióról és a teraszokról (On erosion and terraces), *FK* pp. 1—32
- KRETZÓI, M. (1950), A Zala vidék földtani viszonyai (Geology of the Zala region), *FIÉJ* pp. 97—199, French and Russian summaries
- KRETZÓI, M. (1953), Quaternary Geology and the Vertebrate Fauna, *Acta Geologica*. Tomus II. pp. 67—79
- KRIVÁN, P. (1955), A közép-európai pleisztocén éghajlati tagolódása és a paksi alapszelvény (Climatic division of the Pleistocene of Central Europe and the type section in Paks), *FIK* pp. 363—510, French and Russian summaries
- LÁNG, S. (1938), Folyóterasz tanulmányok (Investigations on river terraces) *FIK* pp. 110—130, German summary
- LÁNG, S. (1949), Teraszképződés (Terrace formation), *HK* pp. 360—365
- LÁNG, S. (1952), Hazánk vízgyűjtőjének felszíne (The surface of the drainage area of Hungary), *HK* pp. 187—196
- LÁNG, S. (1953), Természeti földrajzi tanulmányok az Északmagyarországi Középhegységben (Physiographic studies in the Central Mountains of North Hungary), *FK* pp. 21—64, Russian and German summaries
- LÁNG, S. (1955a), A Mátra és a Börzsöny természeti földrajza (Physical geography of the Mátra and the Börzsöny), *Földrajzi Monográfiák* vol. I, Akadémiai Kiadó, Bp. 512 p., Russian and German summaries
- LÁNG, S. (1955b), Geomorfológiai megfigyelések a Szekszárdi-dombvidéken (Geomorphological observations in the Szekszárd Hill Country), *FK* pp. 151—154, Russian and English summaries pp. 155—156
- LÁNG, S. (1956a), A Központi-Gerece geomorfológiája (Geomorphology of Central Gerece), *FÉ* pp. 265—281, Russian and German summaries
- LÁNG, S. (1956b), A hidrogeográfiai kutatások módszertani kérdései (Methodological problems of the hydrogeographic investigations) with comments, *FÉ* 466 p.
- LÁNG, S. (1957), Természeti földrajzi tanulmányok a Sárköz környékén (Studies on physical geography in the surroundings of Sárköz), *FÉ* pp. 137—154, English and German summaries
- LÁNG, S. (1958a), Természeti földrajzi tanulmányok Sükösd környékén (Studies on physical geography in the surroundings of Sükösd), *FÉ* pp. 175—187, Russian, German and French summaries
- LÁNG, S. (1958b), A Budai-hegység geomorfológiája (Geomorphology of the Buda Mountains), *Budapest természeti képe*, Akadémiai Kiadó, Bp. pp. 149—220

- LÁNG, S. (1958c), A Bakony geomorfológiai képe (Geomorphological patterns of Bakony), *FK* pp. 325—343, German summary pp. 343—346
- LÁNG, S. (1960), A Délkelet-Alföld felszíne (The surface of the South-Eastern Alföld) *Fk.* pp. 31—43 Russian summary
- LÓCZY, L. Sen. (1913), A Balaton környékének geológiája és morfológiája. I. rész. A Balaton környékének geológiai képződményei és ezeknek vidékek szerinti telepődése. I. szakasz. (Geology and morphology of the region of Lake Balaton. Part I. Geological formations of the region of Lake Balaton and their mode of occurrence in the different districts. Section I.), *A Balaton Tud. Tan. Eredm.* vol. I, part I, section I, 614 p.
- LÓCZY, L. sen. (1918), A Magyar Szentkorona országainak leírása (Description of the countries of the Hungarian Holy Crown). Bp. 523 p.
- MAROSI, S. (1953), Morfológiai megfigyelések a Mezőföld déli részén (Morphological observations in the southern part of Mezőföld), *FÉ* pp. 218—233
- MAROSI, S. (1954), Geomorfológiai megfigyelések a Mezőföld Balatontól északkeletre elterülő részén (Geomorphological observations in the sector of Mezőföld situated north-east of Lake Balaton), *FÉ* pp. 433—443
- MAROSI, S. (1955), A Csepel-sziget geomorfológiai problémái (Geomorphological problems of the Csepel-Island), *FÉ*, pp. 279—300, Russian and German summaries
- MAROSI, S. (1958), Budapest és környéke futóhomok-területeinek morfológiája. (Morphology of the quicksand areas of Budapest and its surroundings.) *Budapest természeti képe*, Akadémiai Kiadó, Bp. pp. 300—310
- MAROSI, S. (1959), Vita dr. Pécsi Márton „A Duna-völgy magyarországi szakaszának kialakulása” c. kandidátusi értekezéséről (Comments to the dissertation “Formation of the Hungarian section of the Danube valley” submitted by M. Pécsi for obtaining the degree of candidate of geographical sciences), *FÉ* pp. 113—131
- MAROSI, S. (1960), Felszínfejlődési problémák Belső-Somogyban. *A Magyar Földrajzi Társaság XIV. Vándorgyűlése Zalaegerszegen* (Morphogenetic problems in Central Somogy. XIVth Itinerary Meeting of the Hungarian Geographical Society in Zalaegerszeg), pp. 31—35
- MAROSI, S. (1962a), Belső-Somogy (Internal Somogy), *FÉ* pp. 61—68. German and Russian summaries
- MAROSI, S. (1962b), Vita Somogyi Sándor „Hazánk folyóhálózatának kialakulása” c. kandidátusi értekezéséről. (Comments to the dissertation “Evolution of the drainage system of Hungary”) *FÉ* pp. 131—148
- MAROSI, S.—SZILÁRD, J. (1957), Pleisztocén kovárványos homok Somogyban (Pleistocene red-banded sands in Somogy), *FÉ* pp. 522—523
- MAROSI, S.—SZILÁRD, J. (1958), A Balaton somogyi partvidékének geomorfológiai képe (Geomorphological aspects of the Somogy shore of Lake Balaton), *FK* pp. 347—359, German summary pp. 359—361
- MAROSI, S.—SZILÁRD, J. (1959), A Mezőföld vízrajza (Hydrography of Mezőföld), *MTA Földrajztudományi Kutatócsoport Közlemények* 59. sz. Akadémiai Kiadó, Bp. pp. 319—361
- MIHÁLTZ, I. (1951), A Dél-Dunántúl keleti felének földtani felépítése (Geological structure of the eastern half of Southern Transdanubia), *FIÉJ* pp. 53—59, French and Russian summaries
- MIHÁLTZ, I. (1950), A Duna—Tisza köze déli részének földtani felvétele (Geological survey of the southern part of the area between the Danube and the Tisza), *FIÉJ* pp. 113—143, French and Russian summaries
- MIHÁLTZ, I. (1952), Homokszem nagyság helyszíni meghatározása (Determination of the grain size of sands in the field), *FtK* pp. 51—57, French and German summaries
- MIHÁLTZ, I. (1953), La division des sédiments quaternaires de l'Alföld, *Acta Geologica*. Tomus II, fasc. 1—2, pp. 109—121
- PÁVAI VAJNA, F. (1917), A földkéreg legfiatalabb tektonikus mozgásairól (On the most recent tectonic movements of the earth's crust), *FtK* pp. 249—253 and 63—85 (in 1925)
- PÁVAI VAJNA, F. (1935), Előzetes jelentés a Budapest környéki földi gázkutatásokkal kapcsolatos 1932—1935. évi geológiai felvételtől (Preliminary report on the geological survey undertaken in 1932—1935 in connection with natural gas prospecting in the surroundings of Budapest), *FIÉJ* pp. 879—939, German summary
- PÁVAI VAJNA, F. (1938a), 1936., 1937. és 1938. évi jelentései a Budapest környéki földtani térképezési munkálatairól (Annual reports on geological mapping undertaken in 1936, 1937 and 1938 in the surroundings of Budapest), *FIÉJ* pp. 329—464, in German and Hungarian

- PÁVAI VAJNA, F. (1938b), Az 1938. évi Budapest környéki kiegészítő geológiai felvételi jelentés (Report on the additional geological survey carried out by the author in 1938 in the surroundings of Budapest), *FIÉJ* pp. from 399 in the former publication
- PÁVAI VAJNA, F. (1943), A Dunántúl hegyszerkezete (The tectonics of Transdanubia), *Beszámoló a Földt. Int. Vitailéseinek munkálatairól*. Bp. pp. 213—223, Comments pp. 223—237
- PÁVAI VAJNA, F. (1951), Az alföldi Dunamellék rétegtana és hegyszerkezete (Stratigraphy and tectonics of the Danube region within the Great Hungarian Plain), *FIÉJ* pp. 69—75, French and Russian summaries
- PÉCSI, M. (1950), Völgyfejlődéstörténeti és teraszmorfológiai megfigyelések a Duna-völgy balpartján Budapest és Baja között (Observations concerning the evolution of valleys and the morphology of terraces on the left bank of the Danube between Budapest and Baja), *HK* pp. 260—266
- PÉCSI, M. (1953), Morfológiai megfigyelések a Duna völgyében Dunabogdány—Szentendre és Nógrádverőce—Dunakeszi között (Morphological observations in the valley of the Danube between Dunabogdány—Szentendre and Nógrádverőce—Dunakeszi), *FÉ* pp. 149—175
- PÉCSI, M. (1954), Morfológiai megfigyelések a Duna jobbpartján Szentendre és Budapest között (Morphological observations on the right bank of the Danube between Szentendre and Budapest), *FÉ* pp. 165—179
- PÉCSI, M. (1955a), Eróziós és korráziós völgyek és vízmosások képződése a Duna völgyében Dunaalmás és Nyergesújfalu között (Formation of erosive and corrasive valleys and gullies in the Danube valley between Dunaalmás and Nyergesújfalu), *FÉ* pp. 41—54, German and Russian summaries
- PÉCSI, M. (1955b), Morfológiai adatok a Móri-árok kavicsainak keletkezési körülményeihez (Morphological data on the conditions of formation of the gravels of the Mór Fault Trough), *FÉ* pp. 395—402, German and Russian summaries
- PÉCSI, M. (1956a), Adatok a fiatal kéregmozgások szerepére és mértékére a Duna völgyében (Evidence on the function and dimensions of recent crustal movements in the Danube valley), *Dunántúli Tud. Gyűjtemény*, no. 4, p. 9
- PÉCSI, M. (1956b), A folyókanyarulat és a szakaszjellegváltozás egyes kérdéseiről (On some questions of river-bends and changes in the course type of rivers), *Dunántúli Tud. Gyűjtemény*, no. 5, p. 14
- PÉCSI, M. (1956c), Újabb völgyfejlődéstörténeti és morfológiai adatok a Duna-völgy Pozsony (Bratislava)—Budapest közötti szakaszáról [Contribution to the history of development of the reaches of the Danube valley between Pozsony (Bratislava) and Budapest and to their morphology], *FÉ* pp. 24—41, German and Russian summaries
- PÉCSI, M. (1957a), A magyarországi Duna-teraszok párhuzamosítása a Bécs környéki és a vaskapui teraszokkal (Parallelization of the terraces over the Hungarian reaches of the Danube with those occurring in the surroundings of Vienna and at the Iron Gate), *FK* pp. 259—282, German summary
- PÉCSI, M. (1957b), Kalocsa és Kecel—Kiskőrös környékének geomorfológiai kérdései (Geomorphological problems of the surroundings of Kalocsa and Kecel—Kiskőrös), *FÉ* pp. 421—442, Russian and German summaries
- PÉCSI, M. (1958a), *Budapest természeti képe*, Akadémiai Kiadó, Bp. 248—282
- PÉCSI, M. (1958b), Das Ausmass der quartären tektonischen Bewegungen im ungarischen Abschnitt des Donautales, *Petermanns Geogr. Mitt.* pp. 274—280, in German
- PÉCSI, M. (1959a), A magyarországi Duna-völgy kialakulása és felszínalaktana (Formation and morphology of the Danube Valley in Hungary), *Földrajzi Monográfiák* III. köt. Akadémiai Kiadó, Bp. 345 p., German summary
- PÉCSI, M. (1959b), A negyedkori tektonikus mozgások mértéke a Duna-völgy magyarországi szakaszán (The scale of the Quaternary tectonic movements in the Hungarian section of the Danube Valley), *Geofizikai Közl.* pp. 73—83, German summary
- PÉCSI, M. (1959c), Budapest természeti földrajza (The physical geography of Budapest), Akadémiai Kiadó, Budapest, 416 p.
- PÉCSI, M. (1960a), Die Entwicklung des ungarischen Abschnittes des Donautales, *Sbornik o chest na akademik A. S. Beshkov*, Sofia, pp. 137—147, Russian summary
- PÉCSI, M. (1960b), A Duna—Tisza köze geomorfológiai problémái (Geomorphological problems of the region between the Danube and the Tisza), *FK* pp. 23—29, English summary
- PÉCSI, M. (1960c), Morphogenesis of the Hungarian section of the Danube Valley, *Studies in Hungarian Geographical Sciences*, Publishing House of the Hungarian Academy of Sciences, Bp. pp. 25—37, Russian summary

- PÉCSI, M. (1960d), Der Schuttkegel der Donau auf der Grossen Ungarischen Tiefebene, *Annales Univ. Scienc. Budapestiensis de R. Eötvös Nominata*, Sectio Geologica, Tomus III, pp. 103—134
- PÉCSI, M. (1961a), Opponensi vélemény Pinczés Zoltán „A Zempléni-hegység déli részének természeti földrajza” c. kandidátusi disszertációjáról (Opponent's recension on the dissertation “Physical geography of the southern part of the Zemplén Mountains” submitted by Z. Pinczés for obtaining the degree of candidate of geographical sciences), *FÉ*, vol. X, no. 4, pp. 482—483, 486
- PÉCSI, M. (1961b), A periglaciális talajfagy-jelenségek főbb típusai Magyarországon (Principal types of the periglacial soil frost phenomena in Hungary), *FK* pp. 1—24, German summary
- PÉCSI, M. (1961c), Die wichtigsten Ergebnisse geomorphologischer Forschungen des Quartärs in Ungarn, *INQUA*, Warszawa 1961, Instytut Geol. Odbitka z tomu XXXIV prac Czwart. Europy Środkowej i wschodniej, pp. 281—311, in German
- PÉCSI, M. (1961d), Haupttypen der periglazialen Bodenfrosterscheinungen in Ungarn, Paper presented at the *INQUA* Congress in Warszawa, Abstract of Papers 1961, pp. 24, in German
- PÉCSI, M. (1961e), A negyedkori korrozíós folyamatok hatása a felszín alakulására és az üledék-képződésre Magyarországon. Akad. doktori értekezés. Kézirat. (Influence of the Quaternary corrasive processes on morphological evolution and on sedimentation in Hungary. Dissertation for obtaining the degree of doctor of geographical sciences. Manuscript) 274 p.
- PÉCSI, M. (1962a), Tíz év természeti földrajzi kutatásai (Ten years of physiogeographical research work), *FÉ* pp. 305—336, German and Russian summaries
- PÉCSI, M. (1962b), A Kisalföld geomorfológiai képe (Geomorphological Aspect of the Little Hungarian Plain), *FK* pp. 113—142, Russian summary
- PÉCSI, M. (1962c), Das Ausmass der rezenten Krustenbewegungen in Ungarn. *Ist Intern. Symposium of Recent Crustal Movements*, Leipzig 1962. IUGG, Akademie-Verlag Berlin, pp. 388—395, in German
- PÉCSI, M. (1962d), Die geomorphologische Übersichtskarte Ungarns. *Physisch-geographische Vorträge. Konferenz der Ungarischen Geogr. Gesellschaft und des Geogr. Instituts der Ung. Akad. der Wissenschaften*, Budapest—Balatonszabadi, 1962. p. XIII/1—10. Russian summary
- PÉCSI, M. (1962e), Die Entstehung der Korrasionsfläche. *Physisch-geographische Vorträge. Konferenz der Ungarischen Geogr. Gesellschaft und des Geogr. Instituts der Ung. Akad. der Wissenschaften*, Budapest—Balatonszabadi, 1962. p. X/1—X/9, in German. Russian summary
- PÉCSI, M. (1962f), A magyarországi pleisztocénkori lejtős üledékek és kialakulásuk (Pleistocene slope deposits and their formation in Hungary), *FÉ* pp. 19—35, Russian and German summaries pp. 36—39
- PÉCSI, M. (1963a), Durch flächenhafte Massenbewegung angehäuften periglaziale Hangablagerungen. *INQUA Kommission für die Internationale Quartärkarte von Europa, Exkursionsführer* pp. V/1—3, Manuscript, in German
- PÉCSI, M. (1963b), Lössforschungen und Löss-Chronologie in Ungarn. *INQUA Kommission für die Internationale Quartärkarte von Europa, Exkursionsführer* pp. VII/1—4
- PÉCSI, M. (1963c), Die periglazialen Erscheinungen in Ungarn. (Periglacial phenomena in Hungary), *Petermanns Geographische Mitteilungen*, pp. 161—182, English, Russian and French summaries.
- PÉCSI, M. (1963d), Upper Pliocene — post-Pannonian — Pediments in the Middle Mountains of Hungary, *FK* pp. 195—209, German summary pp. 210—212
- PÉCSI, M.—MAROSI, S.—SZILÁRD, J. (1958), Budapest természeti képe (The physical aspect of Budapest), Akadémiai Kiadó, Bp. 744 p.
- PÉCSI, M.—PÉCSI-DONÁTH, É. (1959), Elemző módszerek alkalmazása a geomorfológiai kutatásban (Application of analytical methods in geomorphological research), *FÉ* pp. 165—175, German summary
- PÉCSI, M.—PÉCSI-DONÁTH, É. (1960), Méthodes de recherche d'histoire de l'évolution des vallées et des terrasses *Annales Univ. Scienc. Budapestiensis de R. Eötvös N.*, Sectio Geologica. Tomus III. p. 135—169, in French
- PÉCSI, M.—SÁRFALVI, B. (1960), Magyarország földrajza (Geography of Hungary), Akadémiai Kiadó, 327 p., Geographie Ungarns Corvina Verlag. Budapest. 1962. In Hungarian and German

- PÉCSINÉ DONÁTH, É. (1958), Duna-teraszkvicsok görgetettségi vizsgálata (Investigations on the roundness of Danube terrace gravels), *FK* 3. sz. pp. 57—75, English summary
- PEJA, GY. (1958), Adatok az agyagos-homokos területek felszíni formáinak ismeretéhez (Contribution to the knowledge of the surface features of clayey-sandy areas.) Kandidátusi értekezés. Manuscript
- PENCK, W. (1924), Die morphologische Analyse, Stuttgart
- PINCZÉS, Z. (1960), A Zempléni-hegység déli részének természeti földrajza. (Physiogeography of the southern part of the Zemplén Mountains.) Kandidátusi értekezés. Manuscript
- PRINZ, GY. (1914), Budapest földrajza (Geography of Budapest), Bp. 110 p.
- PRINZ, GY. (1942), Magyarország földrajza (Geography of Hungary), Bp. 272 p.
- RÓNAI, A. (1956), A magyar medencék talajvize, az országos talajvíztérképező munka eredményei, 1952—1955 (Ground waters of the Hungarian basins, results of the ground water mapping undertaken throughout the country in 1952—1955), *FIK* pp. 1—245, German and Russian summaries
- RÓNAI, A. (1959), Adatok a folyók üledékképző munkájának ismeretéhez (Contribution to the knowledge of the function of rivers in sedimentation), *HK* pp. 1—16, Russian and German summaries
- SCHAFARZIK, F. (1918), A budapesti Duna paleohidrográfiaja (Palaeohydrography of the Danube in its Budapest reaches), *HK* pp. 184—200 in Hungarian, and pp. 206—205 in German
- SCHAFARZIK, F.—VENDL, A. (1929), Geológiai kirándulások Budapest környékén (Geological excursions in the surroundings of Budapest), Bp. 341 p.
- SCHERF, E. (1930), Alföldünk pleisztocén és holocén rétegeinek geológiai és morfológiai viszonyai ezeknek összefüggése a talajalakulással, különösen a sziktalajképződéssel (Geology and geomorphology of the Pleistocene and Holocene beds of the Great Hungarian Plain and their relationship with evolution of the soils, particularly with the formation of alkaline soils), *FIÉJ* pp. 269—273, and pp. 274—301 in German
- SCHERF, E. (1938), Versuch einer Einteilung des ungarischen Pleistozäns auf moderner polyglazialistischer Grundlage, *Verhandlungen der III. Internationalen Quartär-Konferenz*, Wien
- SOERGEL, W. (1925), Die Gliederung und absolute Zeitrechnung des Eiszeitalters, *Forsch. d. Geologie u. Paläontologie*
- SOMOGYI, S. (1956), Megfigyelések Budapest környékén az 1956. január 12-i földrengéstől sújtott területen (Observations in the surroundings of Budapest, in the area affected by the earthquake on 12th of January 1956), *FÉ* pp. 129—134, German summary
- SOMOGYI, S. (1960), Hazánk folyóhálózatának kialakulása. (Evolution of the drainage system of Hungary.) Kandidátusi értekezés. Manuscript
- SOMOGYI, S. (1961), Hazánk folyóvízhálózatának fejlődéstörténeti vázlata (A sketch of the evolution history of the drainage system of Hungary), *FK* pp. 25—50, German summary
- SOMOGYI, S. (1962a), A Vasi-Hegyhát és a Kemeneshát (The Vasi Ridge and the Kemeneshát), *FÉ* pp. 52—58 German and Russian summaries
- SOMOGYI, S. (1962b), Kísérlet a pleisztocén éghajlattípusok néhány hazai értelmezésének párhuzamosítására (Attempt to correlate the Pleistocene climatic types with some occurrences in Hungary according to the interpretation of the Hungarian specialists), *FÉ* pp. 166—168
- SOMOGYI, S. (1962c), A holocén időszakra vonatkozó kutatások földrajzi (hidromorfológiai) értékelése [Geographical (hydromorphological) interpretation of the investigations on Holocene epoch], *FÉ* pp. 185—202, Russian and German summaries
- SÜMEGHY, J. (1939), A Győri-medence, a Dunántúl és az Alföld pannóniai üledékeinek összefoglaló ismertetése (Concise description of the Pannonian sediments of the Győr Basin, Transdanubia and the Great Hungarian Plain), *FIK* pp. 3—159 in Hungarian, and pp. 160—251 in German
- SÜMEGHY, J. (1944), A Tiszántúl (The Trans-Tisza Region). *Magyar tájak földtani leírása*, Bp. 1944. 208 p.
- SÜMEGHY, J. (1947), Adatok az Alföld földtani felépítéséhez (Data on the geological structure of the Great Hungarian Plain), *FIÉJ* pp. 1—39, Russian, German and French summaries
- SÜMEGHY, J. (1948), Földtani adatok a Duna—Tisza köze északi részéről (Geological data on the northern part of the region between the Danube and the Tisza), *FIÉJ* pp. 85—101, French and German summaries

- SÜMEGHY, J. (1950), A Duna—Tisza közének földtani vázlata (Geological sketch of the region between the Danube and the Tisza), *FIÉJ* pp. 233—263, French and Russian summaries
- SÜMEGHY, J. (1951), Medencéink pliocén és pleisztocén rétegtani kérdései (Stratigraphic problems of the Pliocene and the Pleistocene of the Hungarian basins), *FIÉJ* pp. 83—109, French and Russian summaries
- SÜMEGHY, J. (1953), A magyarországi pleisztocén összefoglaló ismertetése (Synthetic treatise of the Pleistocene of Hungary), *FIÉJ* pp. 395—404, French and Russian summaries
- SÜMEGHY, J. (1955), A magyarországi pliocén és pleisztocén (The Pliocene and the Pleistocene of Hungary, Dissertation for obtaining the degree of doctor of geological and mineralogical sciences), Manuscript
- SZABÓ, P. Z. (1955), A fiatal kéregmozgások geomorfológiai és népgazdasági jelentősége Dél-Dunántúlon (Geomorphological and economic importance of recent crustal movements in South Transdanubia), *Dunántúli Tud. Gyűjtemény*, 37 p., Russian and German summaries
- SZABÓ, P. Z. (1957), A Délkelet-Dunántúl felszínfejlődési kérdései (Problems of morphogenetic evolution of South-East Transdanubia), *FÉ* pp. 397—419, German and English summaries
- SZÁDECZKY-KARDOSS, E. (1935), Adatok a görgetési határkérdéshez (Contribution to the question of roundness limit), *FK* pp. 38—39 in Hungarian, and pp. 39—50 in German
- SZÁDECZKY-KARDOSS, E. (1936), Pleisztocén struktúrtalajok az alföldi és a bécsi medencékben (Pleistocene patterned grounds in the Alföld and the Vienna basins), *FK* pp. 213—228, in German
- SZÁDECZKY-KARDOSS, E. (1938), Geologie der rumpfungarländischen Kleinen Tiefebene, Sopron, 444 p.
- SZÉKELY, A. (1961), A Mátra és környezetének kialakulása és felszíni formái. Kandidátusi értekezés. (Formation of the Mátra Mountains and their surface features.) Manuscript
- SZILÁRD, J. (1953), Morfológiai megfigyelések a Mezőföld nyugati részén (Morphological observations in the western part of Mezőföld), *FÉ* pp. 201—217
- SZILÁRD, J. (1954), Geomorfológiai megfigyelések a Mezőföld észak-nyugati részén (Geomorphological observations in the north-western part of Mezőföld), *FÉ* pp. 444—454
- SZILÁRD, J. (1955), Geomorfológiai megfigyelések Kiskőrös és Paks vidékén (Geomorphological observations in the region of Kiskőrös and Paks), *FÉ* pp. 263—278
- SZILÁRD, J. (1960), Külső-Somogy néhány felszínalaktani kérdése. (Some morphological problems of Outer Somogy) *A Magyar Földrajzi Társaság XIV. Vándorgyűlése Zalaegerszegen*, 1960 pp. 36—42
- SZILÁRD, J. (1962), Külső-Somogy (External Somogy), *FÉ* pp. 68—74 German and Russian summaries
- VADÁSZ, F. (1953, 1960), Magyarország földtana (The geology of Hungary), 1st edition 481 p., 2nd edition 646 p.
- VADÁSZ, E. (1954), Magyarország földtani nagyszerkezeti vázlata (A sketch of the major tectonics of Hungary), *MTA Műsz. Tud. Öszt. Közl.* pp. 247—248, Comments 248—255
- VADÁSZ, E. (1955), A Magyar Alföld mélyszerkezete (Deep structure of the Great Hungarian Plain), *Természet és Társ.*, pp. 518—522
- ZÓLYOMI, B. (1936), Tízezer év története virágporszemekben (History of ten thousand years in pollen grains), *Term. tud. Közl.* pp. 504—515
- ZÓLYOMI, B. (1952), Magyarország növénytakarójának fejlődéstörténete az utolsó jégkorszaktól (History of evolution of the flora of Hungary after Last Glaciation), *MTA Biol. tud. Öszt. Közl.* pp. 492—544

ABBREVIATIONS

<i>Bp.</i>	= Budapest
<i>FÉ</i>	= Földrajzi Értesítő
<i>FK</i>	= Földrajzi Közlemények
<i>FIK</i>	= Földtani Intézet Évkönyve
<i>FIÉJ</i>	= Földtani Intézet Évi Jelentése
<i>FK</i>	= Földtani Közlöny
<i>HK</i>	= Hidrológiai Közlöny
<i>KLTE</i>	= Kossuth Lajos Tudományegyetem
<i>VK</i>	= Vízügyi Közlemények

Soon to be published
in the series
STUDIES IN GEOGRAPHY:

APPLIED GEOGRAPHY
IN HUNGARY
(Collection of Papers)

•

GEOGRAPHICAL TYPES
OF HUNGARIAN AGRICULTURE
by
I. Asztalos, Gy. Enyedi
B. Sárfalvi and L. Simon

•

THE INDUSTRY
OF BUDAPEST
by
I. Bencze

•

THE DEMOGRAPHIC
ATTRACTION OF BUDAPEST
by
E. V. Tajti

Distributor:
KULTURA
Budapest 62, P. O. B. 149

